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ATLAS F
FINAL RELIABILITY SUMMARY REPORT
FOR OSTF-2

Volume 3
APPENDICES

15 NOVEMBER 1963

Contract No. AF 04(694)-3

Prepared for
BALLISTIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

Prepared by
TRW Space Technology Laboratories
Based on Atlas F Weapon System
Associate Contractor Documents

TRW SPACE TECHNOLOGY LABORATORIES
THOMPSON RAMO WOOLDRIDGE INC.

6301-6596-RU-000

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ATLAS F

FINAL RELIABILITY SUMMARY REPORT FOR OSTF-II (U)

Test Objective 026 (Math Model) of Integrated Test Plan for WS 107A-1 Operational System Test Facility OSTF-II Category II Including Estimates for Atlas F Operational Weapon System

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This report was prepared by TRW Space Technology Laboratories, and contains information based on and extracted from Atlas F Weapon System Associate Contractor Reports generated under this program. The program was conducted under the technical direction of TRW Space Technology Laboratories.

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This Abstract is Unclassified

ABSTRACT

This report describes the results of the Atlas F Reliability Mathematical Model Study conducted as an analytical part of the OSTF-2 test program. The report is presented in three volumes, and defines development of the models (Volume I), generation of reliability estimates for various combinations of weapon system operating conditions (Volume 2), includes the appendices containing associated studies performed during the program (Volume 3), and the final evaluation of the Reliability of the Weapon System Operating Conditions with an input data cutoff date of 11 December 1963 (Annex No. 1).

CONTENTS

ILLUSTRATIONS

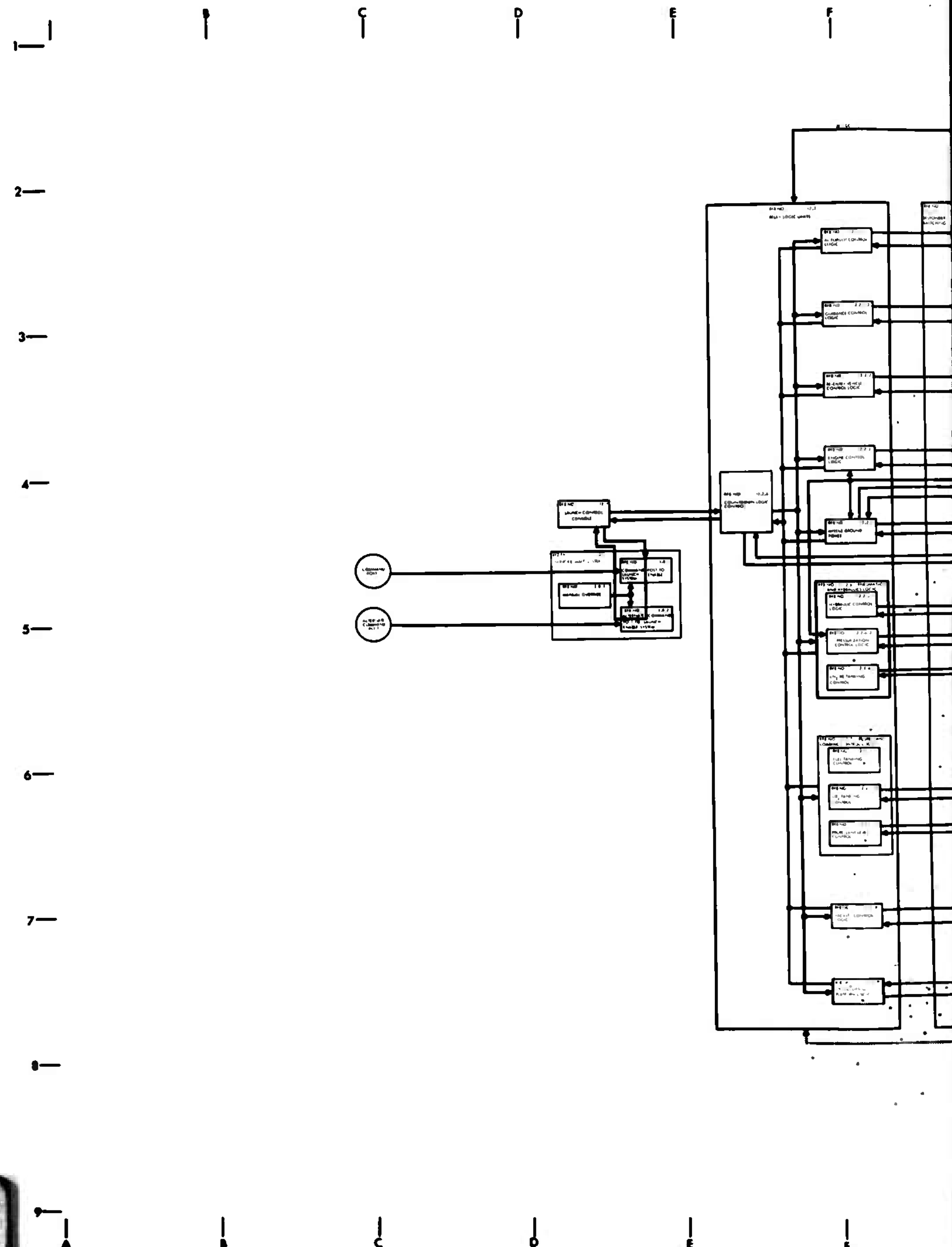
ILLUSTRATIONS (Continued)

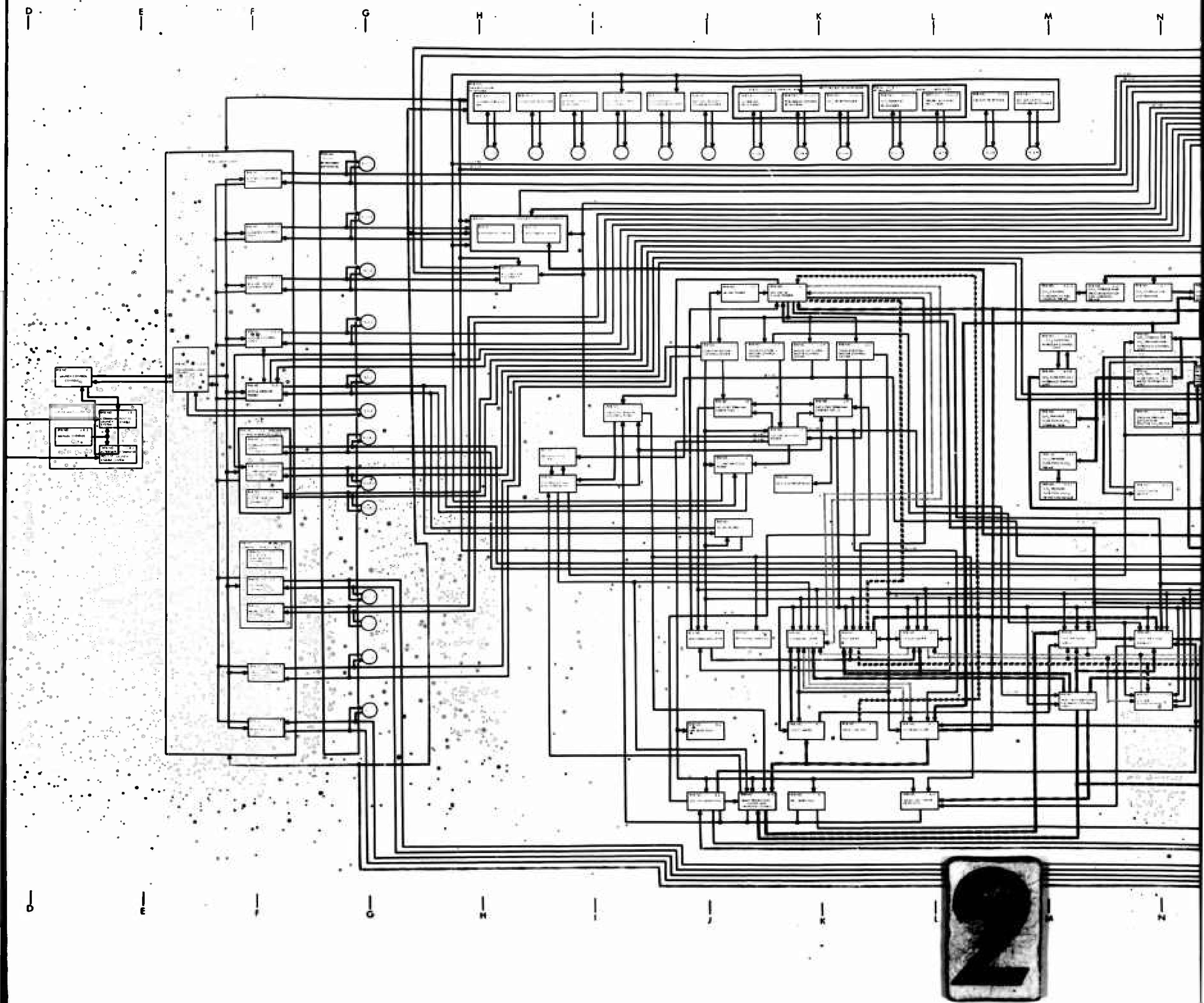
APPENDIX A

FUNCTIONAL DESCRIPTION OF RELIABILITY BLOCKS

A.1 INTRODUCTION

Appendix A presents functional descriptions of each RFB along with functional block diagrams for both missile and ground equipment. Figure A-1 is the functional block diagram for the ground equipment and Figure A-2 is the functional block diagram for the missile equipment. The RFB titles are followed by a figure number (A-1 or A-2) and a letter-number designation which locates the RFB by means of a grid system on every block diagram. Figures A-3, A-4, and A-5 supplement the functional descriptions to show equipment locations in the silo configuration.

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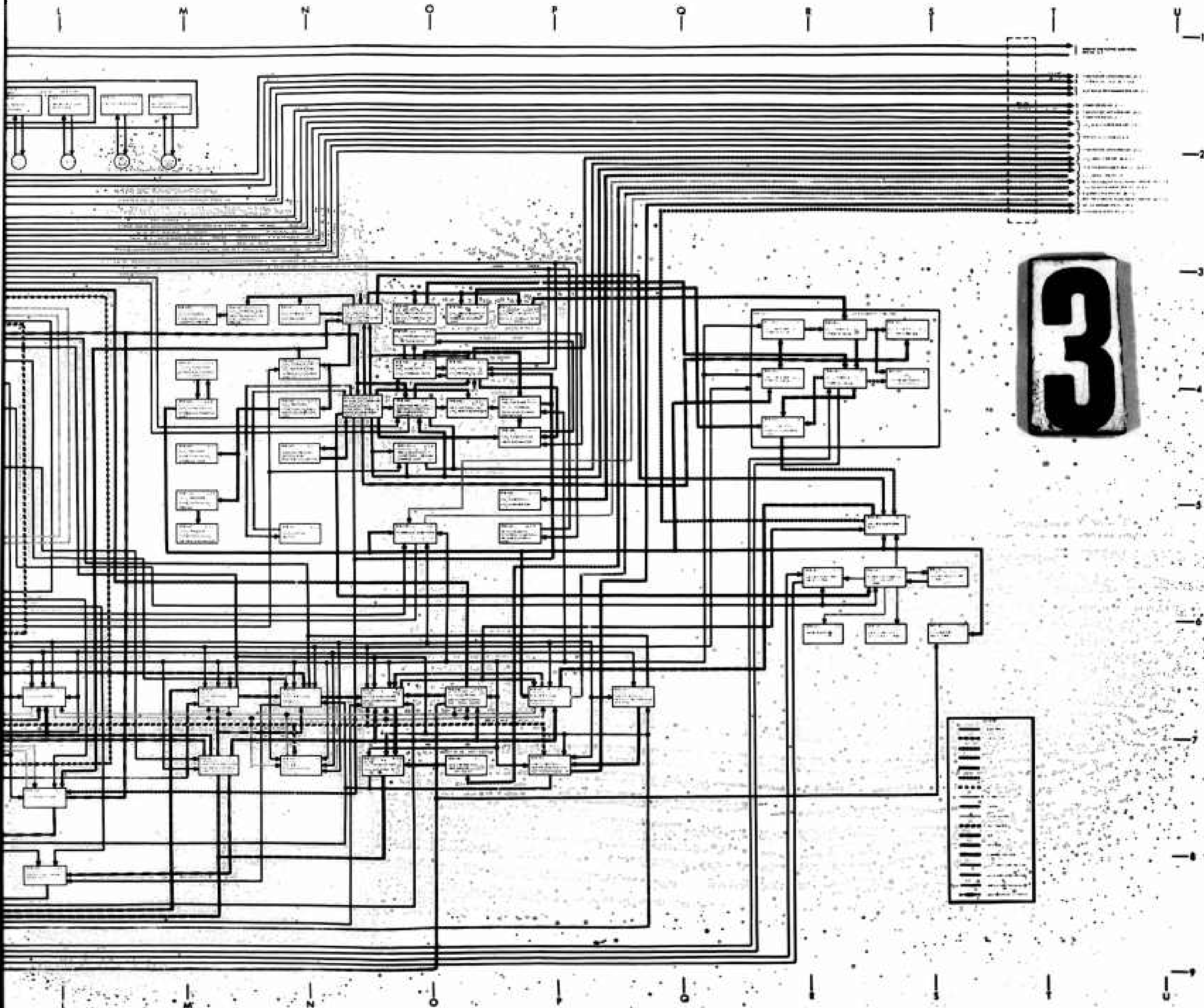
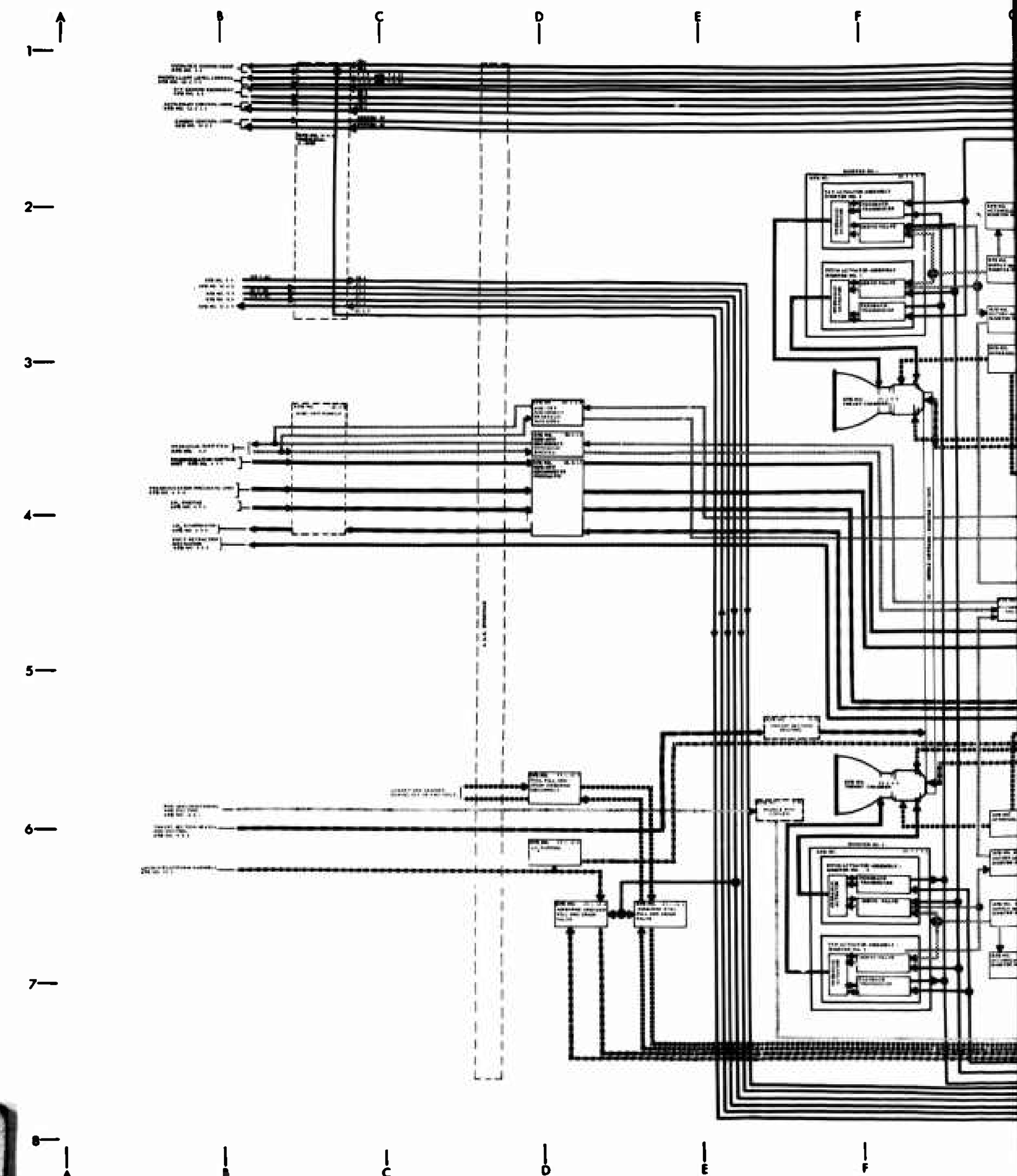


Figure A-1. Functional Flow Diagram of Atlas F Weapon System Operational Ground Equipment



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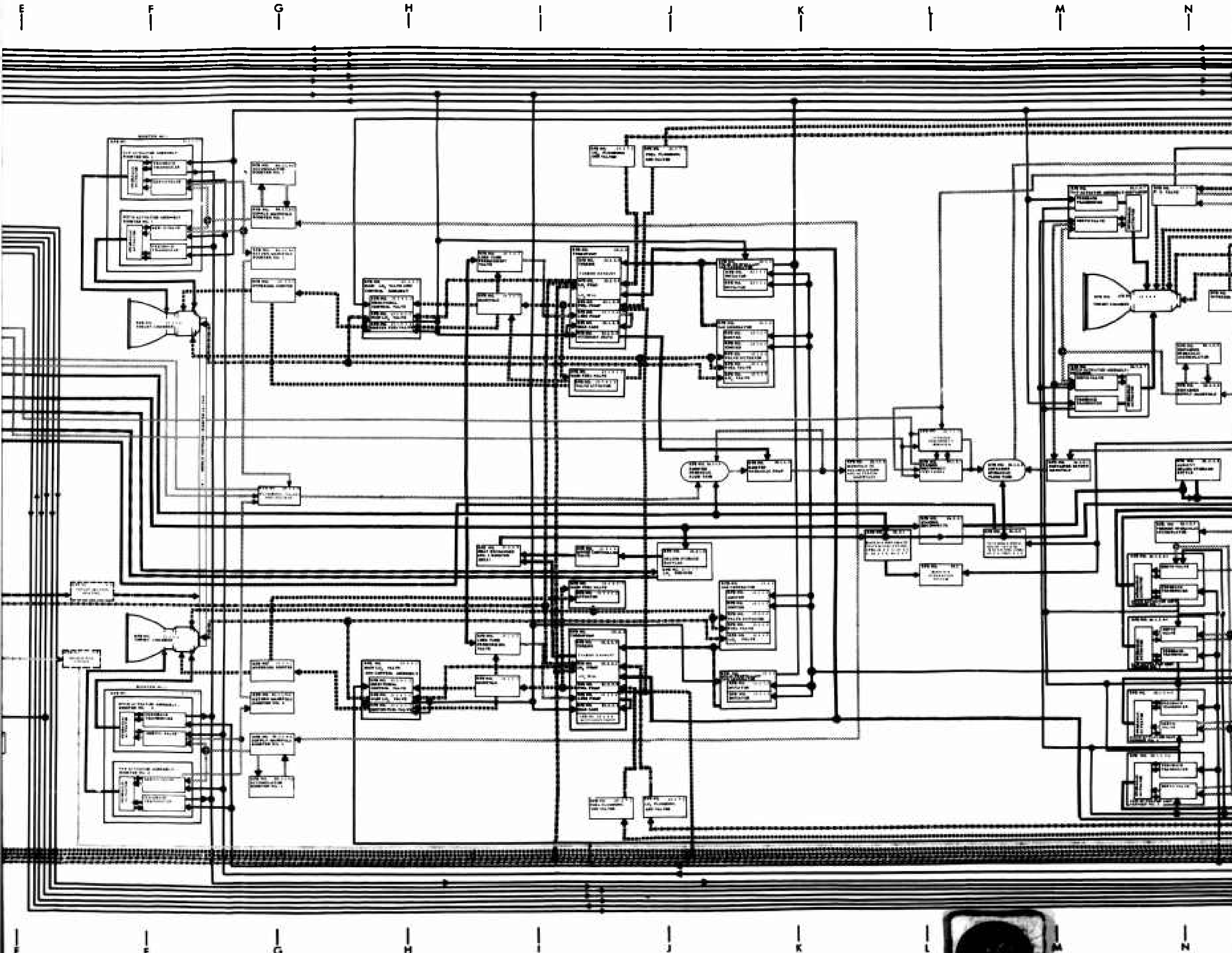

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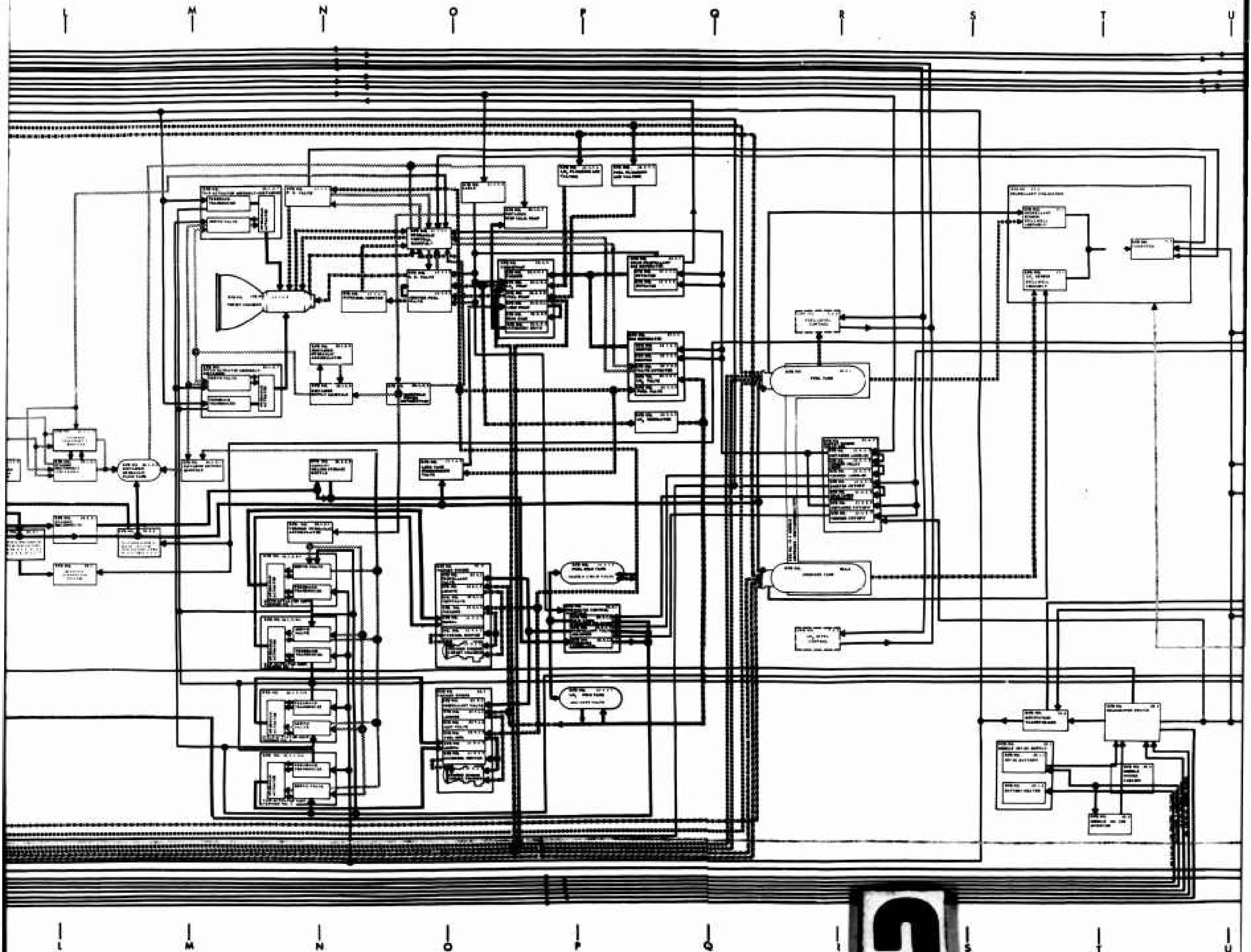

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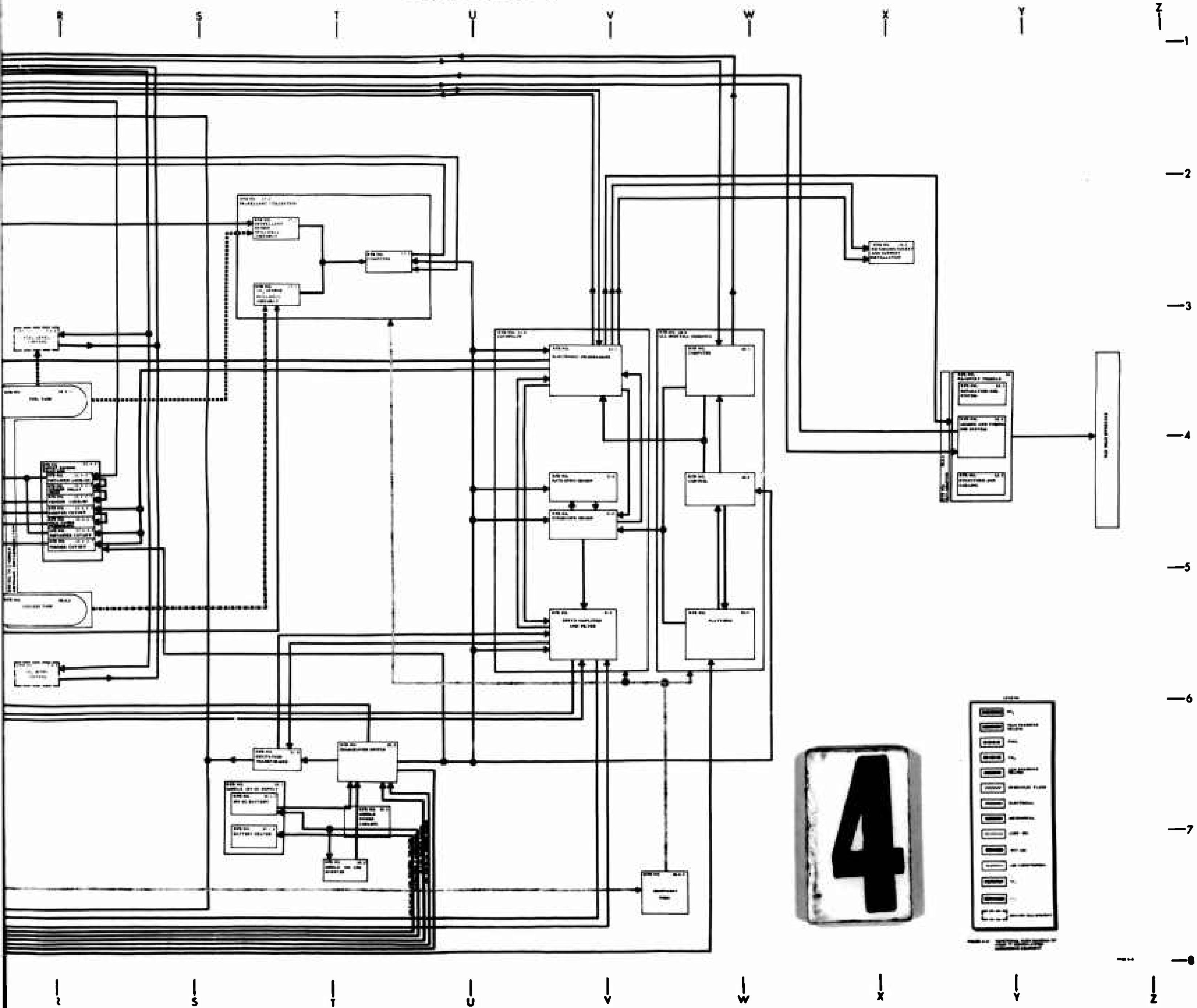
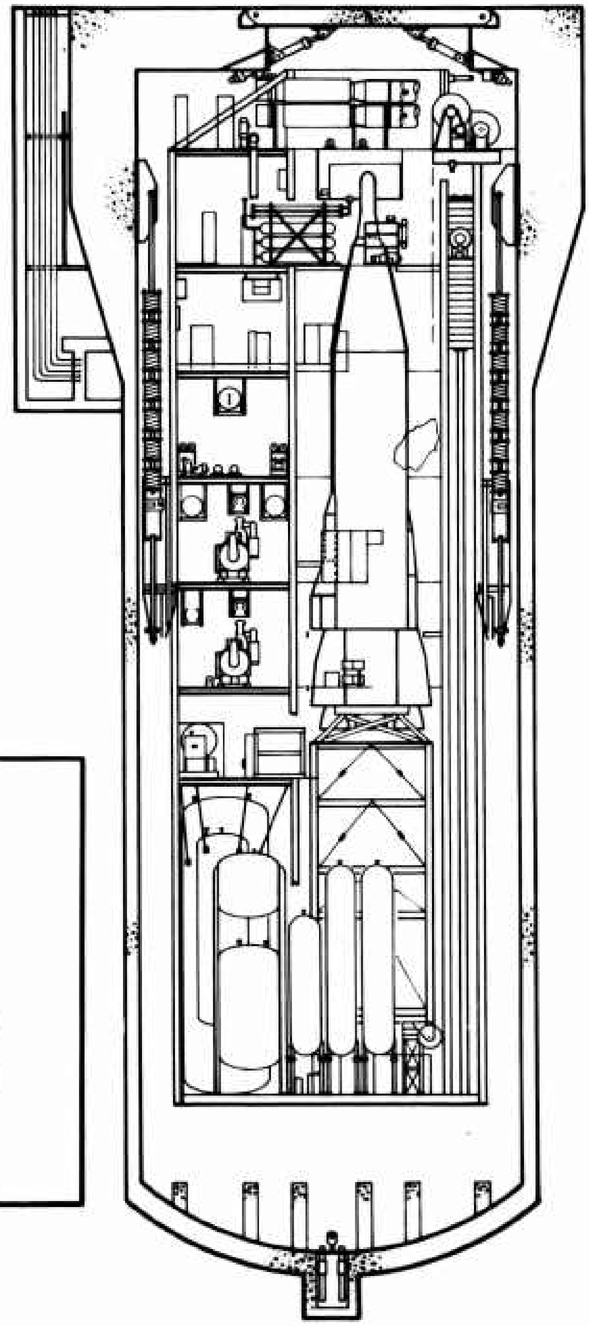


Figure A-2. Functional Flow Diagram of Atlas F Weapon System Missileborne Equipment



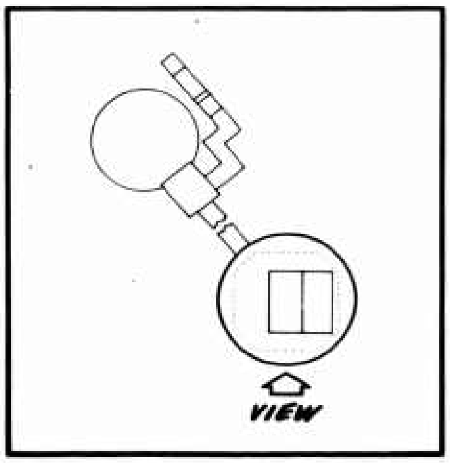


Figure A-3. Atlas F Silo Configuration Cross Section

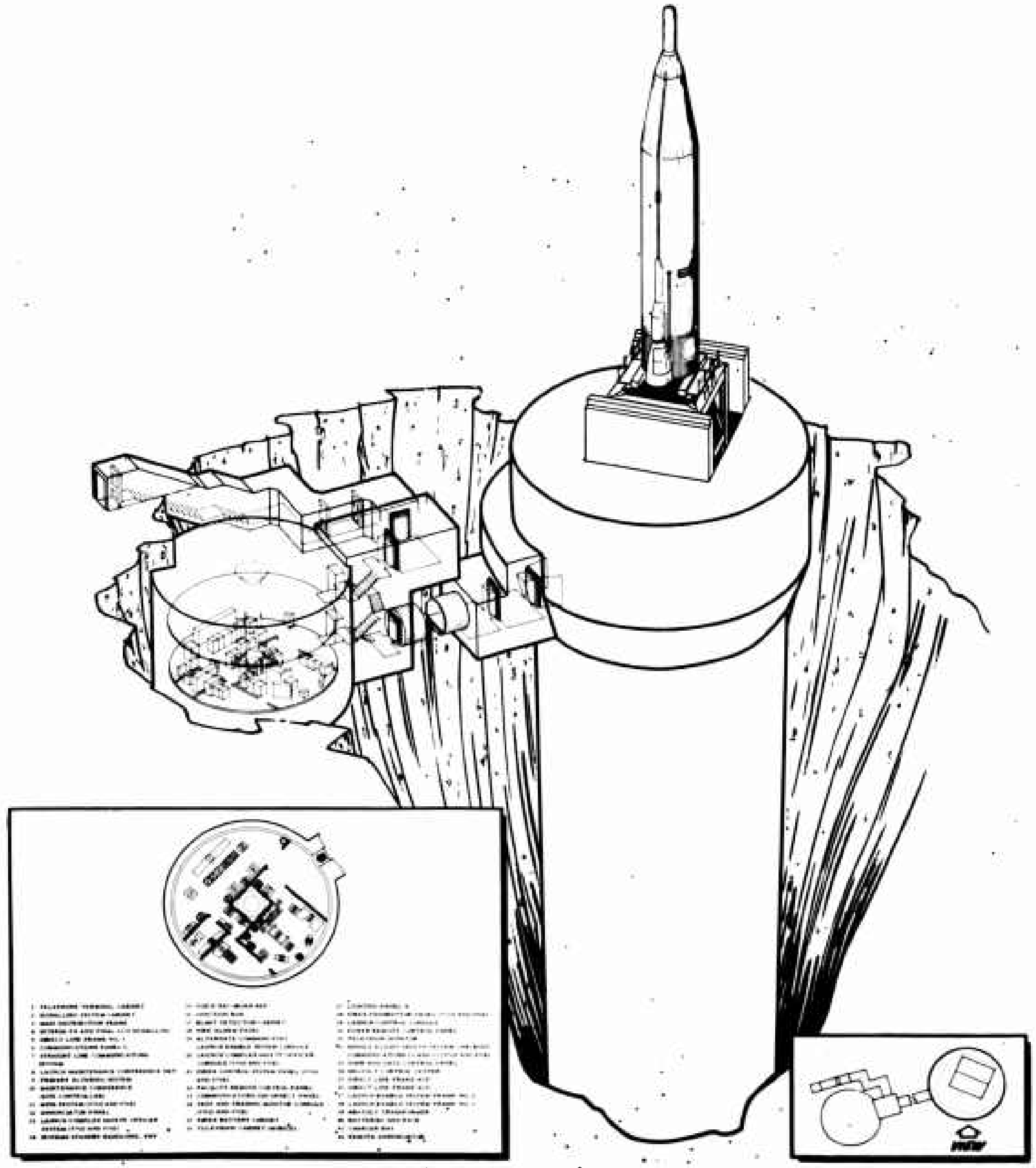


Figure A-4. Atlas F Silo Configuration, Missile in Raised Position

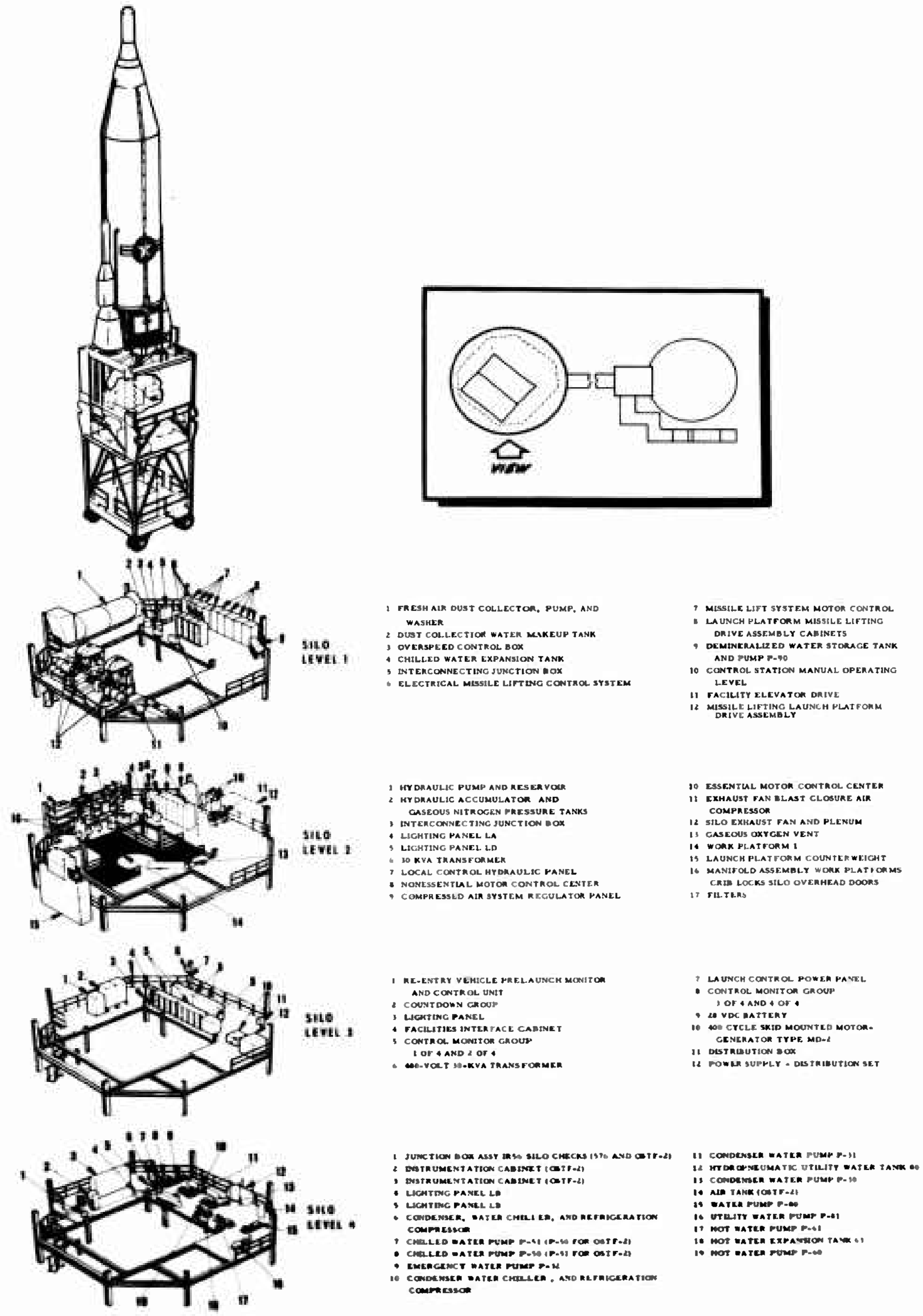
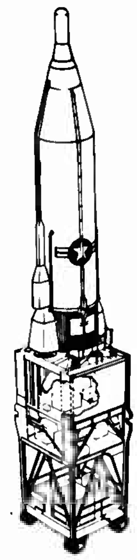
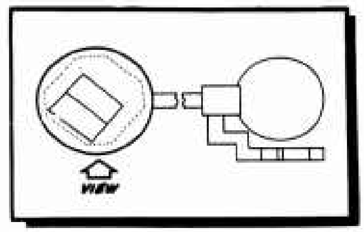
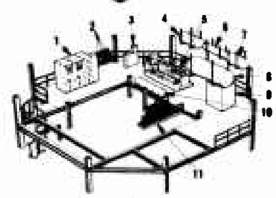


Figure A-5. Atlas F Silo Configuration Equipment

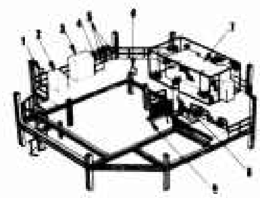






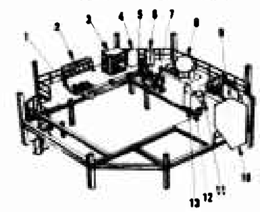
SILO LEVEL 5

1 480-VOLT SWITCHGEAR
2 INSTRUMENTATION BOXES (OSTF-2)
3 SURGE PROTECTION PANEL (EXCEPT OSTF-2)
4 DIRTY LUBE OIL TANK
5 500 KW DIESEL GENERATOR
6 AIR RECEIVER (OSTF-2)
7 CLEAN LUBE OIL TANK
8 HEAT RECOVERY SILENCER
9 WATER HEATER (OSTF-2)
10 DIESEL DAY TANK
11 WORK PLATFORM 2



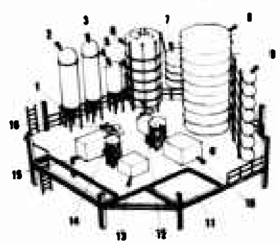
SILO LEVEL 6

1 48-VOLT DC DISTRIBUTION PANEL
2 ELECTRICAL EQUIPMENT CABINET
3 48-VOLT BATTERY RACK
4 48-VOLT BATTERY CHARGER
5 INSTRUMENTATION BOXES
6 INTERCONNECTING JUNCTION BOX
7 MAIN POWER TRANSFORMER
8 ALIGNMENT GROUP SIGHT TUBE
9 WORK PLATFORM



SILO LEVEL 7

1 LO2 TOPPING CONTROL UNIT
2 INSTRUMENTATION BOXES (OSTF-2)
3 LN2 PREFAB
4 GASEOUS OXYGEN DETECTOR
5 LO2 CONTROL PREFAB
6 GASEOUS OXYGEN DETECTOR
7 LO2 FILL PREFAB
8 INSTRUMENT AIR PREFAB
9 PRESSURIZATION PREFAB
10 ALIGNMENT GROUP ENCLOSURE ALIGNMENT GROUP BENCH MARKS
11 FIRE X CONTROL PANEL (VAFB)
12 DIESEL FUEL VAPOR DETECTOR
13 RP-1 DETECTOR



SILO LEVEL 8

1 INSTRUMENTATION BOXES
2 INFLIGHT HELIUM SUPPLY TANK NO. 1
3 INFLIGHT HELIUM SUPPLY TANK NO. 2
4 GROUND PRESSURIZATION SUPPLY TANK
5 VACUUM PUMP
6 LN2 STORAGE TANK AND HEAT EXCHANGER
7 LO2 TOPPING TANK
8 LO2 STORAGE TANK
9 GASEOUS NITROGEN TANKS
10 PNEUMATIC SYSTEM MANIFOLD REGULATOR
11 COLD DISCONNECT PANEL
12 LN2 EVAPORATOR
13 FUEL PREFAB
14 HOT DISCONNECT PANEL
15 PRESSURE SYSTEM CONTROL
16 THRUST SECTION HEATER

Figure A-5. Atlas F Silo Configuration Equipment (Continued)

SYSTEM 1.0—GUIDANCE GROUND EQUIPMENT

RFB 1.1 Countdown Group. (Figure A-1, H-3) The countdown group consists of two racks and an amplifier assembly and performs both the checkout and countdown functions of the inertial guidance system. Functions include zeroing and scaling of the airborne accelerometers, automatic calculation and insertion of prelaunch compensations, coarse and fine alignments of the airborne platform, and computer checks.

RFB 1.2 Alignment Group. (Figure A-1, H-3) The alignment group consists of optical equipment along with associated electronics which functions to retain azimuth alignment of the airborne platform.

SYSTEM 2.0—R/V GROUND EQUIPMENT

(Figure A-1, H-3)

The R/V Ground Equipment is used to verify various R/V functions or perform equipment checks as initiated by launch control. These checks include confirmation and selection of Target A or B, correct battery temperature, Mark 4 R/V use, warhead pressure, assembled continuity, and the start countdown signal. An electrical simulator, which simulates various R/V defects, is used for local verification of R/V Ground Equipment.

SYSTEM 3.0—COMMUNICATIONS

Each of the RFBs shown represent the individual communication tie lines between the three command posts and the LCC. An interlock system (the LES) is shown by means of lines connecting each of the three RFBs with the launch control console. The interlock system is provided to inhibit inadvertent launches and permit authorized launches. The communications necessary to implement a successful launch are signals from the WCP (Wing Command Post), ACP (Alternate Command Post) and the ALCO (Alternate Launch Control Officer). These signals take the form of the absence of a tone from the WCP, ACP and ALCO and are routed via the LES (Launch Enable System). When the three signals are received at the LCC, a relay is affected which allows a launch to be executed. No required voice communication is utilized.

RFB 3.1 WCP to LES. (Figure A-1, B-3) The WCP communication using the LES is a continuous tone. Absence of this tone at the LCC is a signal that the WCP approves a launch.

RFB 3.2 ACP to LES. (Figure A-1, B-3) The ACP communication tone. Absence of this tone at the LCC is a signal that the ACP approves a launch.

RFB 3.3 ALCO to LES. (Figure A-1, B-3) The ALCO communication using the LES is a continuous tone. Absence of this tone at the LCC is a signal that the ALCO approves a launch.

SYSTEM 5.0—AGE ELECTRICAL SYSTEM

RFB 5.1 480-vac, 60-cps Generation and Distribution. (Figure A-1, K-3) This function is defined as the diesel engines, generators, and their controlling equipment necessary to generate and distribute 480-vac, 60-cps power.

RFB 5.1.1 480-vac, 60-cps Generator. (Figure A-1, K-3) This function is defined as the generator and its controlling and starting equipment, and the apparatus necessary to transfer the generated power.

RFB 5.1.2 Power Remote Control Panel. (Figure A-1, K-3) This unit is a panel located in the launch control area which is used to Start-Stop, and synchronize the 480-vac, 60-cps generators remotely.

RFB 5.1.3 Synchronizing Panel. (Figure A-1, K-3) This unit is a panel located in the vicinity of the 480-vac generators which is used to synchronize the generators locally.

RFB 5.1.4 Switchgear. (Figure A-1, K-3) This function contains the bus and circuit breakers which transmit the power to the various motor control centers. This function also includes the facility wiring to all motor control centers.

RFB 5.1.5 Diesel Engine Unit. (Figure A-1, K-3) This function is comprised of the diesel engine, engine instrument board, and other apparatus needed to control and monitor the operation of the diesel engine.

RFB 5.2 Motor Control Centers. This function contains the essential, non-essestial, and launch control motor control centers, each serving as a distributing and controlling center for various facility functions.

RFB 5.2.1 Essential Motor Control Center. (Figure A-1, J-4) This function is defined as the unit itself with all of its controlling apparatus. It is the distributing and controlling center for 480-vac power to facility items under all missions, especially countdown. This function includes the facility wiring to equipments.

RFB 5.2.2 Non-Essential Motor Control Center. (Figure A-1, K-4) This function is defined as the unit itself with all of its controlling apparatus and facility wiring to equipments. It is the distributing and controlling center for 480-vac power to facility items which are needed for missions other than a countdown mission.

RFB 5.2.3 Launch Control Motor Control Center. (Figure A-1, J-4) This function is defined as the unit itself with all of its controlling apparatus and facility wiring to equipments in the launch control center. It is the distributing and controlling center for 480-vac power needed for all missions.

RFB 5.2.4 Missile Lift System Motor Control Center. (Figure A-1, K-4) This function is defined as the MLS (motor control center and launch platform drive cabinet). This function generates, distributes, and controls the different types of power needed for the missile lift system.

RFB 5.2.4.1 480-vac Supply. This function contains the MCC 480-vac supply bus, circuit breakers, fuses, and distribution wiring to other power supplies within the motor control center. Also included are the cables which carry 480-vac power to the 1-hp and 40-hp hydraulic motors.

RFB 5.2.4.2 120-vac Power Supply. This function is defined as the 120-vac transformer, the 120-vac distribution panel with its circuit breakers, internal distribution wiring, and the cables carrying the power to the launch platform drive cabinet.

RFB 5.2.4.3 28-vdc Power Supply. This function is defined as the 23-vdc power pack 1 and distribution wiring connecting it to the dc contactor panel.

RFB 5.2.4.4 DC Contactor Panel. This function is the dc contactor panel and the cables which carry the 28-vdc and 3-vdc to the MLS logic.

RFB 5.2.4.5 Launch Platform Drive Cabinet. This function consists of the launch platform drive cabinets 1 and 2 and the cables which supply both power and control to the various using equipments. The cabinets contain contactors, relays, capacitors, reactors, control-power transformer, magnetic amplifiers, and the other associated components located therein.

RFB 5.3 48-vdc Power System. (Figure A-1, J-3) This function is defined as the 48-vdc batteries, battery charger, and distribution needed for controlling the 480-vac generators either remotely or locally.

RFB 5.3.1 48-vdc Batteries. This function is defined as the batteries and their associated cabling needed for connection to the battery charger and distribution panel.

RFB 5.3.2 48-vdc Battery Charger. This function is defined as the battery charger itself. It recharges the batteries as required.

RFB 5.3.3 48-vdc Distribution Panel. This function is the panel with its controlling breakers and the facility wiring needed to connect it to the various generator control panels.

RFB 5.4 120/208-vac Power Systems. (Figure A-1, K-4) This function is defined as all 120-vac generating devices which supply 120-vac power to equipments in the silo and launch control center.

RFB 5.4.1 120-vac Control Transformer and Panel C. This function converts 480-vac to 120-vac and supplies power to panel C. Panel C distributes this 120-vac power to facilities terminal cabinets 1 and 2 for control purposes, and 120-vac power to operate several facility equipments. This includes the facility wiring to these equipments.

RFB 5.4.2 120-vac Launch Control Power Supply. This function includes a 120-vac transformer, a power and supply panel, and 120-vac, 60-cps cabling.

RFB 5.4.2.1 120-vac Power Supply Transformer. This function consists of a 480 v/120 v step-down transformer and facility wiring needed for power distribution to the power and supply panel and facility equipments.

RFB 5.4.2.2 Launch Control Power and Supply Panel. This function is defined as the power and supply panel itself, which serves as a distribution point for 120-vac power to ground support equipment.

RFB 5.4.2.3 120-vac, 60-cps Cabling. This function is defined as the cabling needed to transport the 120-vac power to the various ground support equipments.

RFB 5.4.3 120-vac SIL Lighting Power. This function includes a 480 v/ 120-vac lighting transformer, a distribution panel, and lighting panels necessary to provide 120-vac, mainly for lighting purposes and power for AGE receptacles.

RFB 5.4.3.1 120-vac Lighting Transformer. This function is defined as the 480 v/ 120-vac step down transformer and the facility wiring to the associated distribution panel. This is the main source of lighting power in the silo.

RFB 5.4.3.2 Lighting Distribution Panel "LD". This function is defined as the distribution panel and the facility wiring to the lighting panels, detection equipment, and AGE receptacles. It serves as a distribution panel for 120-vac powor.

RFB 5.4.3.3 Lighting Panels "LA" and "LB". This function is defined as the panels and the facility wiring used to transport the 120-vac power to lighting equipment.

RFB 5.4.4 120-vac Launch Control Lighting Power. This function includes a 480 v/ 120-vac step-down transformer, a distribution panel, and lighting panel. This is the main source of 120-vac power in the launch control center.

RFB 5.4.4.1 120-vac Lighting Transformer. This function is defined as the 120-vac lighting transformer and the facility wiring to transport the power to facility equipment in the launch control center.

RFB 5.4.4.2 Distribution Panel "B". This function is defined as the distribution panel and the facility wiring used to supply power to the communications equipment and the lighting panel.

RFB 5.4.4.3 Lighting Panel "A". This function is defined as the lighting panel and the facility wiring used to transport 120-vac power of the lighting equipment.

RFB 5.4.5 Water Heater, 120-vac Control Transformer. This function consists of a water heater for the 120-vac Control Transformer.

RFB 5.5 28-vdc Power. (Figure A-1, J-5) This function includes the 28-vdc power supply and distribution box, the 28-vdc cabling, and the emergency 28-vdc cabling, and the emergency 28-vdc batteries.

RFB 5.5.1 28-vdc Power Supply and Distribution Box. This function is defined as the power supply and distribution box itself, which provides all the 28-vdc power needed for all missions in the weapons systems.

RFB 5.5.2 28-vdc Cabling. This function includes all the cabling which transport +28-vdc power to launch control equipments.

RFB 5.5.3 28-vdc Emergency Batteries. This function is defined as the batteries which serve as a backup to the 28-vdc power supply and are used during a return-to-standby mission only.

RFB 5.6 400-cps, 115-vac Power. (Figure A-1, J-5) This function includes the 400-cps motor generator, the ac distribution box, and the 400-cps cabling.

RFB 5.6.1 400-cps, 115-vac Motor Generator. This function is defined as the motor generator which provides all the 400-cps power needed for all missions in the weapons system.

RFB 5.6.2 AC Distribution Box. This function is defined as the ac distribution box which serves as a distribution center for 120-vac, 60-cps and 115-vac, 400-cps power.

RFB 5.6.3 400-cps, 115-vac Cabling. This function includes all the cabling used to transport 400-cps power to launch-control equipment.

RFB 5.7 AGE Receptacles. (Figures A-1, K-5) This function includes all 480-vac and 120-vac, 60-cps receptacles used to connect trailers and other various equipments.

RFB 5.7.1 480-vac, 60-cps Receptacles. This function contains all the 480-vac receptacles needed to connect various trailers and other miscellaneous equipments.

RFB 5.7.2 120-vac, 60-cps Receptacles. This function contains all the 120-vac receptacles needed to connect various trailers and other miscellaneous equipments.

RFB 5.8 Facilities Terminal Cabinet 1. (Figure A-1, K-5) This function contains relays and tie points used to distribute 120-vac control power to and from facility equipment. This includes the facility wiring necessary for connections.

RFB 5.9 Facilities Terminal Cabinet 2. (Figure A-1, K-5) This function contains relays and tie points used to distribute 120-vac control power to and from facility equipment. This includes the facility wiring necessary for connections.

SYSTEM 6.0—AGE PNEUMATICS AND HYDRAULICS SYSTEM

RFB 6.1 GN_2 Transfer and Pressurization Subsystem - LO_2.

RFB 6.1.1 GN_2 Storage for LO_2 Transfer. (Figure A-1, N-3) This RFB consists of five 250-cubic-foot-capacity GN_2 bottles manifolded together and all stub-ups which are physically an integral part of the bottles. The GN_2 is stored under 4000 psig pressure. The function of these bottles is to provide a pressure source for LO_2 transfer.

RFB 6.1.2 GN_2 Transfer Function-Pressurization Prefab. (Figure A-1, N-3) The RFB consists of the GN_2 transfer function of the pressurization prefab and comprises all GN_2 lines valves, hardware, stub-ups within the physical boundaries of the prefab pertaining to this function. The function of the pressurization prefab is to regulate and control the flow of GN_2 to the ullages of LO_2 storage and topping tanks for LO_2 transfer, to the topping Control Unit for LO_2 topping, transfer to the fuel pressurization tank, and to the NCU. In addition, it is used to filter and control the flow of GN_2 for resupplying the GN_2 storage vessels. The prefab is provided with a graphic control panel for performing the manual GN_2 resupply operations.

RFB 6.1.3 GN_2 Function (Topping Control Unit). (Figure A-1, O-3) This RFB consists of the GN_2 portion of the TCU. It comprises all GN_2 valves, lines, hardware, and stub-ups within the physical boundaries of the prefab pertaining to this function. The function of the GN_2 portion of the TCU is to operate the valves that control the LO_2 flow from topping tank to the missile. In addition, it is used to control the drain and vent of the main 10-inch line (valves N-60 to N-80) prior to L/P rise.

RFB 6.1.4 GN_2 Pressurization (LO_2 Topping Tank). (Figure A-1, O-3) This RFB consists of GN_2 diffuser assembly, and stub-up located in the LO_2 topping tank. This function provides GN_2 pressurization for the LO_2 topping tank pressurization and LO_2 transfer.

RFB 6.1.5 <u>GN_2 Pressurization (LO_2 Storage Tank)</u>. (Figure A-1, O-3) This RFB consists of the GN_2 diffuser assembly and stub-up located in the LO_2 storage tank. Its function is to provide GN_2 pressurization for storage tank pressurization and LO_2 transfer operations.

RFB 6.1.6 <u>Interconnecting Lines</u>. This RFB contains all GN_2 lines and stub-ups in System 6.1 that are not an integral part of the tanks of prefabs and includes the following lines:

a) Line OAF-1 runs from GN_2 fill connection to the pressurization prefab stub-up. It contains a gimbal joint, valve, and fill connection. The function of this line is to carry GN_2 to the prefab for recharging the GN_2 storage bottles used for LO_2 transfer.

b) Line OVP-1 containing three gimbal joints, runs from the pressurization prefab to the surface above the silo cap. The function of this line is to relieve excessive pressures (GN_2-GO_2) from the GN_2 pressurization lines to LO_2 storage and topping tanks, and from the line PDX from the LO_2 fill and LO_2 control prefabs and the PDU.

c) Lines NOP-2 1/2 and NOP-1 from the pressurization prefab to the five GN_2 storage tanks. The function of this line is to recharge the five GN_2 bottles and to supply the pressurization prefab with GN_2 from the five storage bottles.

d) Line NOT 1-6 runs from the pressurization prefab to the LO_2 storage tank. The function of this line is to carry GN_2 to the LO_2 storage tank for pressurization purposes.

e) Line NOT 2-2 runs from the pressurization prefab to LO_2 topping tank. The function of this line is to carry GN_2 to the LO_2 topping tank for pressurization purposes.

f) Line 27-27054-2 from the pressurization prefab to the TCU. The function of this line is to convey GN_2 from the pressurization prefab to the TCU.

g) 27-27005-9/16 from pressure prefab to TCU. The function of this line is to convey GN_2 from the pressurization prefab to the TCU for valve control.

h) Lines PDX-2 1/2, OVC-3/4, and OCF-3/4. Line PDX-2 1/2 runs from the PDU to the pressurization prefab. Line PDX tees into line OVC-3/4, to the LO_2 control prefab and line OVF-3/4 to the LO_2 fill prefab. The function of these lines is to vent GN_2 and GO_2 from the LO_2 control prefab, LO_2 fill prefab, and PDU through the pressurization prefab.

i) Line 27-27044-2 runs from the TCU to the LO_2 probe in line OFM-10. The function of this line is to drain the main 10-inch LO_2 line in C/D or DPL sequences.

RFB 6.2 GN_2 Transfer and Pressurization Subsystem (Fuel and LN_2).

RFB 6.2.1 GN_2 Storage (for LN_2 Transfer for the NCU, and for the Fuel Prefab). (Figure A-1, N-4) This RFB consists of a pair of 250-cubic-foot-capacity GN_2 bottles manifolded together, and all stub-ups which are physically an integral part of the bottles. The GN_2 is stored under 4000 psig pressure. The function of these GN_2 storage bottles is to provide a pressure source for LN_2 transfer, for the nitrogen control unit, and for the fuel prefab.

RFB 6.2.2 GN_2 Transfer Function (PDU). (Figure A-1, N-4) This RFB consists of the GN_2 transfer portion only of the PDU and comprises the GN_2 lines, valves, hardware, and stub-ups within the physical boundaries of the PDU pertaining to instrument air backup and pressurization line NSD. The function of the facility GN_2 portion of the PDU is to provide instrument air back up and GN_2 to line NSD—the nitrogen pressurization line to the LN_2 prefab and to the LN_2 storage tank.

RFB 6.2.3 GN_2 Transfer Function (LN_2 Storage Tank). (Figure A-1, M-4) This RFB consists of the GN_2 portion of the LN_2 storage tank and is comprised of a diffuser assembly and a stub-up that are physically an integral part of the tank. The function of the GN_2 portion of the LN_2 storage tank is to pressurize and vent the tank.

RFB 6.2.4 GN_2 Transfer Function (LN_2 Prefab). (Figure A-1, M-5) This RFB consists of the GN_2 portion of the LN_2 prefab and comprises all GN_2 lines, valves, hardware, and stub-ups within the physical boundaries of the prefab that pertain to the GN_2 function. The function of the GN_2 portion of the prefab is to transfer GN_2 for pressurization of

the LN_2/He heat exchanger and to provide a means of venting the GN_2 from the LN_2 storage tank and LN_2/He heat exchanger.

RFB 6.2.5 <u>GN_2 Transfer Function (LN_2/He Heat Exchanger)</u>. (Figure A-1, M-5) This RFB consists of the GN_2 portion of the LN_2/He heat exchanger, and comprises all GN_2 lines hardware, and stub-ups within the physical boundaries of the heat exchanger that pertain to the GN_2 function. The function of the GN_2 portion of the heat exchanger is to provide pressure to empty the LN_2 container.

RFB 6.2.6 <u>GN_2Function, Nitrogen Control Unit (NCU)</u>. (Figure A-1, M-4) This RFB consists of the GN_2 portion of the nitrogen control unit, and comprises all valves, lines, and stub-ups within the physical boundaries of the NCU. The function of the NCU is to regulate, control, and distribute high pressure GN_2 to: 1) the hydraulic pumping unit, 2) the APCHE start up and relay box, 3) the LO_2 fill and drain valve retraction cylinder, and 4) the engine service unit. In addition, it supplies GN_2 through four hoses to the GN_2 charge panel and various other equipment. (Hose reel 3 goes to the MDU.)

RFB 6.2.7 <u>GN_2 Storage and Pressurization Function (Fuel Loading Prefab)</u>. (Figure A-1, M-3) This RFB consists of the GN_2 storage and pressurization portion of the fuel loading prefab and is comprised of GN_2 valves, pressurization tank, pressurization tank lines, hardware, and stub-ups within the physical boundaries of the fuel loading prefab that pertain to this function. Normally, this function is used during standby to apply two-psig GN_2 pressure through the fuel pressurization tanks to missile fuel leveling tanks for purging and pressurization during draining sequences, and for pressurizing the missile fuel leveling tank during temperature stabilization.

RFB 6.2.8 <u>GN_2 Funtion (HPU)</u>. (Figure A-1, M-4) This RFB consists of GN_2 pressurization lines and connections of the HPU. The function of the GN_2 portion of the HPU is the pressurization of the hydraulic reservior, and the first and second stages.

RFB 6.2.9 Interconnecting Lines. This RFB contains all GN_2 lines and stub-ups in System 6.2 that are not an integral part of the tanks or prefabs and consists of the following:

a) Line NPS-2 runs from the PDU and "tees" into line NPS-3.

b) Line NPS-3 interfaces with the LN_2 storage tank and the LN_2 prefab. The function of lines NPS-2 and NPS-3 is to provide GN_2 pressure from the PDU to the LN_2 storage tank and the LN_2 prefab.

c) Line NPS-4 runs from the LN_2 prefab to the heat exchanger. The function of this line is to provide the heat exchanger with GN_2 pressurization (via the LN_2 prefab) when required during LN_2 drain operations.

d) Line NPP-1 runs from fill connector N-20 to the pressurization prefab. This line contains a vent valve, fill connector, and a flex joint. The function of this line is to carry GN_2 to the pressurization perfab from the GN_2 fill connector.

e) Line NTP-1 from the pressurization prefab forms a tee and interfaces with two GN_2 storage bottles. This line provides GN_2 to the GN_2 pressure to the pressurization prefab.

f) Line NFP-1/2 runs from the fuel loading prefab to the pressurization prefab. This line provides the fuel pressurization tank with GN_2.

g) Line NSD-1 runs from the pressurization prefab to the PDU. This line provides GN_2 to the PDU for LN_2 transfer.

h) Line NEX1-4, containing three ball joints, interfaces with the LN_2 prefab on one end, and vents to the atomsphere on the other. The function of this line is to vent excess GN_2 pressures in pressurization lines to the LN_2 storage tank and LN_2 prefab for LN_2 transfer.

i) Lines NSU1-1 and NSU2-1, and 27-80158. Line NSU2-1 runs from the pressurization prefab to the bottom of the elevator platform where it connects to the elevator disconnect panel quick disconnect. Line NSU1-1 runs from the line NSU2-1 to the top of the elevator where it can reconnect with the elevator reconnect panel after the panel has risen. Line 27-80158 runs from the NCU to the the NSU disconnect: the line also tee's off and goes to the L/P lower disconnect panel. The function of this line is to supply GN_2 to the NCU

j) Line NPM routes GN_2 to the following:

(1) Engine service trailer

(2) Ground half of LO_2 fill and drain valve retraction cylinder through line 27-27045 (Ref: 6.2.9.17.)

k) Line NHS routes GN_2 to the hydraulic pumping unit.

l) Line NUS routes GN_2 to the APCHE stub-up and relay box.

m) Line (Spare 27-80158 -147 -153) routes GN_2 to the pod air conditioner electrical switch box.

n) Line NVP-2 interfaces with the fuel load prefab at one end, the other end vents to the atmosphere at the silo cap; it contains a flex joint. This line provides a vent for the missile fuel leveling tank.

o) Line NFF-3/8 interfaces with the fuel loading prefab and tee's into FFP-3. This line contains check valve F-13. The function of this line is to carry GN_2 to fuel line FFP-3.

p) Line NDP-3/8 interfaces with the fuel loading prefab and tee's into FFM-4. This line contains check valve F-9. The function of this line is to carry GN_2 to fuel line FFM-4.

q) Line 27-27045 1/4 (from line NPM to LO_2 fill and drain valve retractions cylinder) contains hand valve N-77 (27-02415-1). The function of this line is to supply GN_2 pressure to the retraction cylinder.

RFB 6.2.10 <u>GN_2 Control Function (Fuel Loading Prefab)</u>. (Figure A-1, M-3) This RFB consists of the GN_2 control portion (lines C-500-3/8) of the fuel loading prefab and comprises valves and lines (2) pertaining to this function.

The purpose of the GN_2 control function is the control of the GN_2 pressurization valves in the fuel loading prefab.

RFB 6.3 Helium Subsystem and GN_2 Ground pressurization Subsystem.

RFB 6.3.1 Ground Pressurization and Routine-Use GN_2 Bottle. (Figure A-1, N-4) This RFB consists of the GN_2 ground pressure bottle including stub-ups. The function of this RFB is to supply GN_2 for missile propellant tank pressurization during standby, and for the hydraulic accumulator rack bottle.

RFB 6.3.2 In-Flight He Bottle No. 1 and 2. (Figure A-1, N-5) This RFB consists of in-flight He including stub-ups. The functions of this RFB are as follows:

a) To supply emerging He to the pressure control unit

b) To supply He to the pressure control unit to bring the missile tank pressure up to flight pressure at the start of countdown.

c) To supply He to the missile ambient He bottle during the first two minutes of countdown.

RFB 6.3.3 Interconnecting Lines. This RFB consists of all the interconnecting lines from the in-flight He bottles and the ground pressurization GN_2 bottle to the pneumatic distribution unit. The function of these lines is to supply He and GN_2 to the PDU and to recharge the He and GN_2 ground pressure bottles.

a) Line NPC-1 runs from the ground pressure bottle (GN_2) to the PDU. It includes relief valve PV207.

b) Line HAS-1 runs from in-flight He bottle No. 1 to the PDU. It contains 1/2-inch relief valve RV205.

c) Line HAS2-1 runs from in-flight He bottle No. 2 to the PDU. It contains 1/2-inch relief RV206.

RFB 6.3.4 He and GN_2 Ground Pressurization Function (Pneumatic Distribution Unit). Figure A-1, N-4) This RFB consists of all lines and valves pertaining to the He and GN_2 ground pressurization function of the PDU and excludes GN_2 lines NSD and NPS (incorporated in RFB 6.2.2), the instrument air portion (incorporated in RFB 8.16), and the

electrical portion (incorporated in RFB 12.6.6). The functions of this portion of the PDU are:

a) To control the resupply cycle of He in-flight and GN_2 ground pressurization bottles.

b) To distribute He from the No. 1 and No. 2 in-flight bottles.

c) To distribute GN_2 to the hydraulic accumulator rack bottles.

d) To provide GN_2 to the PCU for propellant tank pressurization during standby.

RFB 6.3.5 Ground Pressurization Function (Pressurization Control Unit). (Figure A-1, O-4) This RFB consists of all lines and valving within the PDU with the exception of the instrument air portion (Refer to RFB 8.1.7) and the electrical portion (Refer to RFB 12.6.7). The function of the PCU is to control and route, semi-automatically or manually, the flight pressurization gases from storage via the PDU to propellant tanks of the missile.

RFB 6.3.6 Pressurization Function, Helium Charge Unit (HCU). (Figure A-1, O-4) This RFB consists of the pressurization function only of the HCU, excluding the instrument control portion (Refer to RFB 6.3.9) and the electrical portion (Refer RFB 12.6.9). It comprises the 4.0-cubic-foot He storage bottle (311) and supply lines HCS (including instrument He charge valve 317), and valving within the confines of the unit itself pertaining to this function. The function of this RFB is to maintain He pressure in the A/B shrouded He spheres during launch platform rise, prior to launch, and to provide pressurization to the missile fuel tank under emergency conditions.

RFB 6.3.7 He Function (LN_2/He Heat Exchanger). (Figure A-1, O-4) This function consists of the He portion of the heat exchanger. This portion of the heat exchanger is comprised of twelve loops of 1/2-inch tubing, each loop containing approximately 70 feet of tubing, and He stub-ups. The function of this RFB is to supply chilled gaseous He to the coaxial line for transfer to the A/B He sphere during countdown.

RFB 6.3.8 Interconnecting Lines.

a) Line HHE-1 runs from the pneumatic distribution unit to the LN_2/He heat exchanger. The function of this line is to convey He to the LN_2/He heat exchanger.

b) Line HES-3/4 runs from the pneumatic distribution unit to the pressurization control unit. The function of this line is to provide an "emergency" source of He to the PCU.

c) Line HCS-9/16 runs from the pneumatic distribution unit to the L/P disconnect and from the L/P disconnect to the HCU. This line includes L/P disconnect and two couplings. The function of this line is to convey He to the helium charge unit.

d) Line HSM interfaces the helium charge unit at the coupling upstream of gage 301 and ties into line HRS (He portion of coaxial line) upstream of the L/P rise-off disconnect. The function of this line is to provide He pressurization to the He spheres during elevator rise prior to launch.

e) Line HRS runs from the LN_2/He heat exchanger through and including L/P disconnects to and including the missile rise-off disconnects. The function of this line is to carry chilled He through a coaxial line containing LN_2 to the missile He spheres.

f) Line HMC interfaces at the pneumatic distribution unit line, coupling downstream of orifice 27, and goes through the L/P disconnect panel to the missile rise-off disconnect. The function of this line is to supply He to the missile ambient He bottle.

g) Line HOP interfaces the PCU at line HOP coupling and the missile rise-off disconnect through and including the L/P disconnect. This function excludes line HOS (in the HCU) upstream of the L/P rise-off disconnect. The function of this line is to convey GN_2 or He for missile LO_2 tank pressurization.

h) Line HFP runs from the pressurization control unit through and including the L/P disconnects to the missile rise-off disconnect. The function of this line is to convey GN_2 or He for missile fuel tank pressurization.

i) Line HOS interfaces at the line HOS coupling on the HCU and the main GN_2/He supply line HOP. The function of this is to convey the pressure level of the missile LO_2 tank pressurization line to the HCU.

j) Line HFS interfaces at the line HFS coupling on the HCU and the main GN_2/He supply line HFP. The function of this line is to convey the pressure level of the missile fuel tank pressurization line to the HCU and, under "emergency" conditions, provides He for fuel tank pressurization.

k) Line HNS interfaces pneumatic distribution unit stub-up HNS and pressurization control unit stub-up HNS. The funtion of this line is to carry the normal He and GN_2 supply to the pressurization control unit.

l) Line HFD-1 runs from the He fill connection 250 to the pneumatic distribution unit. This line contains two valves and a gimbal joint. The function of this line is to carry He for resupply of the in-flight He bottle.

m) Line NFD-1/4 runs from nitrogen fill connector N-21 to the pneumatic distribution unit. This line contains a valve and a gimbal joint. The function of this line is to carry GN_2 for recharge of the GN_2 ground pressurization bottle.

n) Line NHA runs from the pneumatic distribution unit to the hydraulic accumulator rack GN_2 bottles. The function of this line is to carry GN_2 to the hydraulic accumulator rack GN_2 bottles.

o) Line HCX1-3 runs from the pressurization control unit to the silo cap. This line serves as an emergency LO_2 tank pressure vent.

p) Line HCX2-3 runs from the pressurization control unit to the silo cap. This line serves as an emergency fuel tank pressure vent.

q) HFP-3 sensing line, which interfaces with main He supply line HFP to the missile fuel tank, terminates at the surface in a stub-up for connection to MDU hose 61 during checkout.

r) HOP-3 sensing line, which interfaces with the main He supply line, HOP, to the missile LO_2 tank, terminates at the surface in a stub-up for connection to MDU hose 60 during checkout.

RFB 6.3.9 Helium Instrumentation Control Function (Helium Charge Unit). (Figure A-1, P-5) RFB consists of the He instrumentation control portion of the HCU and comprises helium bottle 318 and all valves and controllers that pertain to this function. The pressurization function is covered under RFB 6.3.7 and the electrical under RFB 12.6.9 The function of this RFB is to control the helium valves in the HCU and monitor missile fuel and LO_2 tank pressures at all times.

RFB 6.4. Hudraulic Subsystem. (Figure A-1, O-5)

RFB 6.4.1 Hydraulic Pumping Unit (Hydraulic function). This RFB, which consists of the hydraulic supply function of the HPU and contains two similar hydraulic pressure sections using a common reservoir, a drive motor, and a blower, is subdivided as follows:

RFB 6.4.1.1 First Stage. The first stage of the HPU supplies pressurized hydraulic fluid to the missile booster hydraulic system and consists of that portion of the HPU that performs this function. In addition, it includes the "common" 30 hp motor of the HPU. The function of this RFB is to fill, bleed, check out, and pressurize the booster section hydraulic system.

RFB 6.4.1.2 Second Stage. The second stage of the HPU supplies pressurized hydraulic fluid to the missile sustainer/vernier hydraulic system and consists of that portion of the HPU that performs this function. In addition, it includes the "common" 2 hp blower assembly. Its function is to fill, bleed, checkout, and pressurize the sustainer/vernier hydraulic system.

RFB 6.4.1.3 Hydraulic Reservoir. This RFB consists of the hydraulic reservoir common to both stages of the HPU and includes hydraulic fill and supply lines (up to but excluding motorized shut-off valve 55 and back pressure valve 63), instrument lines, associated valves, and guages, excepting GN_2 supply lines. The function of this RFB is to store and supply hydraulic fluid for both stages of the HPU.

RFB 6.4.2 Interconnecting Lines.

a) Line PPB, pressure line from HPU to the missile rise-off disconnects. It includes a hose assembly and a rise-off coupling.

b) Line PRB, return line from missile rise-off disconnects to the HPU. It includes a hose assembly and a rise-off coupling.

c) Line PPS, pressure line from the HPU to the missile rise-off disconnects. It includes a hose assembly and a rise-off coupling.

d) Line PRS, return line from missile rise-off disconnect to the HPU. It includes a hose assembly and a rise-off coupling.

RFB 6.5 LN_2 Transfer Subsystem.

RFB 6.5.1 LN_2 Function (LN_2 Prefab). (Figure A-1, O-4) This RFB consists of the LN_2 portion of the LN_2 prefab and comprises all LN_2 lines, valves, hardward, and stub-ups within the physical boundaries of the prefab pertaining to this function. The function of this RFB is to filter and control the flow of LN_2 to the storage tanks and LN_2/He heat exchanger during the resupply cycle, and to control LN_2 transfer through the coaxial line to the missile He sphere shrouds during countdown.

RFB 6.5.2 LN_2 Function (LN_2 Storage Tank). (Figure A-1, O-4) This RFB consists of the LN_2 portion of the 4,000-gallon LN_2 storage tank, including manway and associated vent lines and valving. The function of the LN_2 storage tank is to store LN_2 for transfer to the missile helium sphere shrouds during countdown.

RFB 6.5.3 LN_2 Function (LN_2/He Heat Exchanger). (Figure A-1, P-4) This RFB consists of the LN_2/He heat exchanger, including manway, associated vent lines, and valving. The function of this portion of the heat exchanger is to cool the helium to -300°F for delivery through the coaxial line to the shrouded airborne helium bottles.

RFB 6.5.4 LN_2 Evaporator. (Figure A-1, P-5) This RFB consists of the LN_2 evaporator. The function of this RFB is to evaporate the LN_2 overflow from the missile He bottle shrouds. It also evaporates LO_2 from topping lines during the hold period.

RFB 6.5.5 Vacuum Pump and Associated Plumbing and Fittings (For LN_2 Storage Tank and LN_2/He Heat Exchanger). (Figure A-1, P-4) This RFB consists of the vacuum pump common to the LN_2 storage tank and LN_2/He heat exchanger and the associated plumbing and fittings, excluding the instrument air portion covered under RFB 8.1.8.3.2. The function of this RFB is to maintain insulation vacuum in the vacuum packets of the LN_2 storage tank-LN_2/He heat exchanger.

RFB 6.5.6 Interconnecting Lines. This RFB consists of all LN_2 interconnecting lines and stub-ups in the LN_2 transfer subsystem.

a) Line NLS - 2 runs from LN_2 fill connector 260 to the LN_2 prefab. It contains a relief valve and a flex joint. This line conveys LN_2 during resupply to the LN_2 prefab for transfer to the LN_2 storage tanks and the LN_2/He heat exchanger.

b) Line NLS - 1-1/2 carries LN_2 from the LN_2 prefab to the LN_2/He heat exchanger.

c) Line NLS - 2 carries LN_2 from the LN_2 storage tank to the LN_2 prefab.

d) Line NLF - 2 (the facility portion of LN_2 supply line) runs from the LN_2 prefab to the crib-mounted coaxial line. The function of this line is to provide LN_2 to the coaxial line.

e) Line 27-80157 runs from the missile firewall to the LN_2 evaporator. The function of this line is to carry LN_2 overflow from the missile He bottle shrouds to the evaporator. It also carries LO_2 from the topping lines during the hold period (through branch line 27-27006-7, covered in RFB 7.2.6.8).

f) Line 27-80904 is the AGE portion of the LN_2 coaxial supply line NFL-2 which interfaces at the facility stub-up and the L/P disconnect. (This section of the line is crib-mounted.)

g) Line NLF-2 on 27-80161 consists of the AGE portion of the LN_2 coaxial supply line, which interfaces at the lower launch platform disconnect and the upper L/P disconnect or missile rise-off disconnect. This line assembly consists of -371, -415, hose 27-08021 -801, -441, 125, and hose 27-08222-9, terminating in disconnect 27-81405-3 (note: coaxial assembly on -465).

h) Line NLF-1 on 27-80161 consists of the AGE portion of the LN_2 coaxial supply line, which interfaces at the lower L/P disconnect or the missile rise-off disconnect. This line consists of line assembly -119, -135, -121, hose 27-08222-23, terminating in disconnect 27-81405-3.

RFB 6.5.7 <u>LN_2 Instrumentation Function</u>. (Figure A-1, O-4) This RFB includes the LN_2 sensing lines NMU_1, NMU_2, NLM_1, and NLM_2 from the LN_2/He heat exchanger and the LN_2 storage tank to the LN_2 prefab. The function of this RFB is to sense the liquid level of the LN_2 storage tank and the LN_2/He heat exchanger.

SYSTEM 7.0 — PROPELLANT LOADING SYSTEM

RFB 7.1 LO_2 Loading Subsystem

RFB 7.1.1 LO_2 Storage — LO_2 Storage Tank. (Figures A-1, R-3) This RFB consists of the LO_2 storage function of the LO_2 storage tank and includes all valves and stubups which pertain to this function. The function of this RFB is to store LO_2 during standby, ready for cooldown of LO_2 lines, and transfer to the missile during countdown.

RFB 7.1.2 LO_2 Topping Tank. (Figures A-1, R-4) This RFB consists of the LO_2 storage portion of the LO_2 topping tank and all LO_2 valves and stubups which are physically an integral part of the tank. The function of this tank is to store LO_2 for the following uses:

a) Cooling down the LO_2 topping ground and missile plumbing.

b) Final topping of missile.

c) Maintaining LO_2 level in the missile tank while holding.

RFB 7.1.3 LO_2 Control Prefab. (Figures A-1, S-3) This RFB consists of the LO_2 portion of the LO_2 control prefab and consists of all LO_2 lines, valves, and hardware with the physical boundary of the prefab. The function of this prefab is to filter and control the flow of LO_2 from the storage tank to the missile tank during cooldown of the LO_2 lines, and rapid and fine load portions of countdown. It is also used to control the flow of LO_2 from missile during a missile drain sequence. Hydraulic snubbers are provided with the rapid and fine load valves to adjust independently the opening and closing times. These snubbers also prevent the valves from slamming shut with a resultant damaging pressure surge upstream of the valves.

RFB 7.1.4 LO_2 Topping Control Unit. (Figures A-1, R-4) This RFB consists of the LO_2 portion of the topping control unit and comprises all LO_2 valves, lines, and hardware within the TCU pertaining to this function.

h) Interconnecting lines (lines OFM-10 inch and 27-27723). This function consists of the main10-inch LO2 fill line to missile. This line is subdivided into two sections—one which is a "facility," the other an "AGE" responsibility.

1) Facility portion consists of line OFM-10 inch from LO_2 control prefab to L/P disconnect panel (10 inch disconnect valve).

2) AGE portion which consists of LO_2 line missile fill and drain (27-27723, sheet 1 of 2) from L/P disconnect panel to missile rise-off disconnect. This line includes the following "replaceable" components:

- 10 inch disconnect assembly (27-27780-1).
- 10 inch gimbal joint L-56 (27-02487).
- 10 inch pressure balance joint L-57 (27 -02486).
- 10 inch swivel joint L-58—excluding reaction cylinder (covered under RFB 7. 2. 10).
- Duct 27-27838-3).
- Missile rise-off coupling (27-02922).

RFB 7. 1. 6 LO2 Storage Tank Vacuum Pump and Associated Plumbing and Fittings. (Figures A-1, R-3) This RFB consists of LO_2 storage tank vacuum pump and associated plumbing.

The function of this RFB is to maintain low pressure in the vacuum jacket of the LO_2 storage tank.

RFB 7. 1. 7 LO2 Topping Tank Vacuum Pump and Associated Plumbing and Fittings. (Figures A-1, R-4) This RFB consists of the LO2 topping tank vacuum pump and associated plumbing and fittings.

The function of this RFB is to maintain low pressure in the vacuum jacket of the topping tank.

RFB 7. 1. 8 LO2 Instrumentation Function. (Figures A-1, S-4) This RFB consists of the LO2 sensing lines OMU1, OML1, OMU2, and OML2 from the LO2 storage and topping to, and including, the liquid level indicators LLI-1 and LLI-2 in the pressurization prefab. These lines include valves L28 and L29. The function of this RFB is to sense the LO_2 level in the LO_2 storage and topping tanks.

The function of this unit is to filter and control the flow of LO_2 from the LO_2 topping tanks to the missile. Specifically, the equipment is capable of controlling and monitoring the following LO_2 transfer operations:

a) Transfer of LO_2 from topping tank to cooldown the LO_2 topping ground system and missile ducting and engine turbo pumps at beginning of countdown sequence.

b) Transfer of LO_2 from topping tank to fill missile to 100 percent level during the final phase of countdown sequence, i.e., at start of commit and prior to L/P rise.

c) Maintaining LO_2 level in the missile during hold period.

RFB 7.1.5 Interconnecting Lines

a) Line OFP-2 runs from LO_2 fill connection to the LO_2 fill prefab. The line contains flex joint FJ-10 and fill connector L20.

b) Line OST-3 (27-27024) runs from TCU to L/P disconnect assembly (27-02922-check valve L-53).

The function of this line is to convey LO_2 from the topping control unit to the elevator L/P disconnect.

c) Topping line from L/P disconnect to missile rise-off disconnect panel line 27-27016 interfaces with the L/P 3-inch disconnect valve and the missile rise-off disconnect. The line contains a 3-inch flex hose (L-55).

A subsiding line (tube assembly 27-27006-7) branches off from line 27-27016. It contains a checkvalve and an orifice. This line conveys LO_2 to the LN_2 evaporator line and hence to the LN_2 evaporator tank during a hold.

d) Line OST-3 (27-27024) runs from the LO_2 topping tank to the TCU.

e) Line OST-3 (27-27015) runs from LO_2 fill prefab to line 27-27024, going to TCU (replaces OFS-2 inch).

f) Line OFT-10 inch runs from LO_2 storage tank to the LO_2 control prefab. It contains a 15-inch long removable flanged section for OSTF installation only.

g) Line OFC-2 inch runs from LO_2 fill prefab to line OFT-10 inch.

RFB 7.2 Propellant Level Control System

RFB 7.2.1 LO_2 Level Control. (Figures A-2, R-5) This RFB consists of two transducer assemblies, one of which is mounted on the LO_2 tank at the 95 percent level and comprises a 1/2-inch tube containing a liquid sensitive transducer and a threaded plug assembly. The other is mounted on the boil-off valve and comprises one stillwell and three liquid sensitive transducers. The function of this RFB is to sense the liquid level in the missile LO_2 tank during countdown and hold and transmit this signal to LO_2 logic unit which controls LO_2 flow from the LO_2 control prefab and the topping control unit.

RFB 7.2.2 Fuel Level Control. (Figures A-2, R-3) This RFB consists of the missile fuel sensing probe and comprises a probe assembly and four transducer assemblies. The function of this RFB is to sense the fuel level in the missile fuel tank during fuel loading and stabilization, and to transmit this signal to the logic unit.

RFB 7.2.3 Propellant Level System Cabling. This RFB consists of all the missile cabling necessary for the operation of the system.

SYSTEM 8.0 FACILITY SYSTEMS

RFB 8.1 Utility Water System. (Figures A-1, K-7) Water is taken from the base utility water main through a 3-inch line and stored in an underground tank. From the tank, water is pumped into the system by either one of two pumps in parallel, depending upon the demand. System pressure is maintained by means of a hydro-pneumatic tank. Included in the system are drinking fountains, emergency showers, eye washers, fire hoses, a fog system and the LCC domestic water. This system also supplies water to the dust collector and condenser water system.

RFB 8.1.1 Water Storage. (Figures A-1, K-7) This block consists of water storage tank, tank vent line, LLA-1, and the tank level control system.

RFB 8.1.2 Utility Water Pump. (Figures A-1, K-7) This block consists of the utility water pump and motor (P-81).

RFB 8.1.3 Hydro-Pneumatic Tank. (Figures A-1, K-7) This block consists of a hydro-pneumatic tank level gauge 80, PI 82, PS 80, PRV, and a 2-inch line to drain.

RFB 8.1.4 Lines and Valves. (Figures A-1, K-7) This block consists of all valves and interconnecting utility water lines except as called out in RFB 8.3.1.

RFB 8.2 Condenser Water Subsystem. (Figures A-1, K-6) Water from the cooling tower is circulated by pump to the chilled water refrigerating systems, diesel jacket, air compressor, and return. During normal operating conditions the tower cools 620 gallons of water per minute from 108°F to 90°F. During cold weather some water bypasses the tower to maintain water temperature in the silo at 90°F. During L/P rise, the pumps and the refrigerant systems are shut down. A signal from the blast detection system will shut down the recirculation pumps and turn on the emergency pump which delivers utility water to the system to be discharged to the silo sump (CT-1).

RFB 8.2.1 Cooling Tower. (Figures A-1, K-6) This block consists of the cooling tower and its motor, fan, level control valve, temperature sensors, drain, and overflow lines.

RFB 8.2.2 Pump. (Figures A-1, K-6) This block consists of a pump and its motor.

RFB 8.2.3 Chemical Pot. (Figures A-1, K-6) This block consists of the chemical pot feeder.

RFB 8.2.4 Line and Valves. (Figures A-1, K-6) This block consists of all lines and valves in the condenser water subsystem except those mentioned in RFB 8.2.1. The chemical pot, RFB 8.2.3, bypass line is included in this block.

RFB 8.2.5 Electric Controls. (Figures A-1, K-6) This block consists of local control thermostats and temperature indicators.

RFB 8.3 Chilled Water System. (Figures A-1, L-6) The chilled water is circulated by one of two pumps, in parallel, through two water chilling units, in parallel, and then to the end users and back. The chillers, which are both normally operating, are refrigeration units. An expansion tank is located at the end of the distribution system. Demineralized make-up water is fed into the expansion tank. The following items are supplied by the chilled water unit: Pod air conditioning unit, LCC cooling coil, electronic cabinets' fan coil unit, and missile enclosure fan coil unit.

RFB 8.3.1 Pump. (Figures A-1, L-6) This block consists of a pump and motor.

RFB 8.3.2 Water Chiller Unit. (Figures A-1, L-6) This block consists of a water chiller unit.

RFB 8.3.3 Expansion Tank. (Figures A-1, L-6) This block consists of expansion tank (TK50), its drain line, level gauge, and 0.5-inch line to and from the liquid level controller.

RFB 8.5.4 Expansion Tank. (Figures A-1, K-6) This block consists of the expansion tank and level gauge.

RFB 8.5.5 Lines and Valves. (Figures A-1, K-6) This block consists of all interconnecting lines and valves in the hot water system.

RFB 8.6 Fire Detection Subsystem. (Figures A-1, J-7)

a) Power Set. This unit converts 120 vac supplied from circuit 15 of lighting panel "A" in the LCC to 24 vdc to run the fire alarm system. It also contains several 2-volt wet cell batteries capable of supplying normal current to the system for a minimum of 30 hours when facility line power is not available.

b) Annunciator Control Unit. This unit is a 10-circuit lamp and buzzer fire alarm system monitor-controller located on Level 2 of the LCC.

c) 180 Degree Fire Detectors. This unit detects a temperature rate-of-rise greater than 15°F/ per minute or a temperature greater than 180°F within the volume monitored by the individual detector. This function consists of three of these units located in the instrumentation equipment building. They react by closing normally open contacts and completing a circuit through the annunciator.

d) Alarm Bells. This function consists of one alarm bell on each of the two levels of the LCC. The bells are actuated simultaneously by a fire detector manual alarm box, or when a fire zone test pushbutton circuit is closed.

e) Red Light Units. This function consists of a red warning light mounted near and operating simultaneously with each of the alarm bells in (d).

f) 180 Degree Fire Detectors. This unit detects a rate-of-rise of temperature of greater than 15°F/per minute or a temperature greater than 180°F within the volume monitored by the individual detector. This function consists of two of these units, both located on Level 1 of the LCC. They react by closing normally open contacts and completing a circuit through the annunciator.

g) Terminal Cabinet. This function is an electrical line terminal cabinet located on Level 2 of the silo.

RFB 8.3.4 Lines and Valves. (Figures A-1, L-6) This block consists of all interconnecting lines and the valves in the chilled water system.

RFB 8.4 Demineralized Water System. (Figures A-1, J-6) This system stores and distributes demineralized water to the chilled and hot water systems, and to the diesel cooling system. Demineralized water is brought in by truck and put in the storage tank through a fill line from the surface. On demand, the water is pumped to the end users.

RFB 8.4.1 Storage Tank. (Figures A-1, J-6) This block consists of the storage tank and its vent line, drain line, and level gauge.

RFB 8.4.2 Pump. (Figures A-1, J-6) This block consists of a pump (P-90) and motor.

RFB 8.4.3 Lines and Valves. (Figures A-1, J-6) This block consists of all interconnecting lines and valves from the fill line at grade to (a) chilled water expansion tank, RFB 8.3.3 (b) hot water expansion tank, RFB 8.5.4, and (c) diesel engine, RFB 5.1.5.

RFB 8.5 Hot Water System. (Figures A-1, K-6) This system circulates hot water from the heating units to the end users and back. Either one of two pumps, in parallel, feeds the water to the diesel exhaust heat exchanger. From there it flows through the hot water boiler where any deficiency in temperature is made up. It then flows to the missile enclosure fan coil unit and the thrust section heater before returning to the pumps. The expansion tank is tied into the system at the pump suction line. Make-up demineralized water is fed into the expansion tank.

RFB 8.5.1 Pump. (Figures A-1, K-6) This block consists of a pump and motor.

RFB 8.5.2 Diesel Exhaust Heat Exchanger. (Figures A-1, K-6) This block consists of the diesel exhaust heat exchanger.

RFB 8.5.3 Hot Water Boiler. (Figures A-1, K-6) This block consists of the electric hot water boiler, its drain lines, safety valve, and low water cutoff.

h) 180 Degree Fire Detectors. This unit detects a rate-of-rise of temperature of greater than 15°F/per minute or a temperature greater than 180°F within the volume monitored by the individual detector. This function consists of 26 of these units located on Levels 1, 2, 3, 4, 5, 6, 7, 7A and 8 of the silo. They react by closing normally open contacts and completing a circuit through the annunciator.

j) Red Lights Units. This function consists of three red warning lights mounted on silo Levels 2, 4, and 8 that operate simultaneously with each of the alarm bells in k) and p) of this RFB.

k) Alarm Bells. This function consists of an alarm bell on silo Level 2 and one on silo Level 8. These bells are actuated simultaneously when a fire detector manual alarm box or fire zone test pushbutton circuit is closed.

m) Manual Fire Alarm Boxes. This function consists of four manually initiated fire-alarm boxes installed on silo Levels 2, 4, 6 and 8. When actuated, a normally open contact in the box is closed, completing a circuit through the annunciator unit to the facility network of alarm bells and red lights.

n) Explosion Proof Fire Detectors. This function consists of seven explosion-proof fire detectors installed in the missile enclosure area of the silo on Levels 2, 3, 4, 6, 7 and 8. These units detect a rate-of-rise of temperature of greater than 15°F/per minute or a temperature greater than 180°F within the volume monitored by the individual detector. They react by closing normally open contacts and completing a circuit through the annunciator.

p) Explosion-Proof Alarm Bell. This function consists of a single explosion-proof alarm bell mounted within the missile enclosure area of the silo on Level 4. This bell is actuated when a fire detection manual alarm box or fire zone test pushbutton circuit is closed.

RFB 8.7 RP-1 Detection Subsystem. (Figures A-1, K-8)

a) RP-1' Detection Unit. This function consists of a detection unit which takes in air samples from eight selected stations in the missile enclosure area and analyzes them by means of a combustion cell for RP-1 content. When RP-1 content of the air reaches 20 percent of the lower explosive limit (LEL), audio and visual alarms are initiated, the launch platform purge exhaust system is initiated, and relay LAR3

completes the circuit for the telephone disconnect which leads to the facilities interface cabinet. When 40 percent concentration is reached, visual alarms are given, the audio alarms continue, the launch platform purge exhaust system discontinues, relay HAR3 completes the circuit for the telephone disconnect on the facilities interface cabinet, and relay HAR2 completes the circuit that initiates the fire fog system in the missile enclosure area. The detection unit consists of a vacuum pump, station selector panel, control unit, and a monitor unit housed in a cabinet with associated cables, piping, and accessories.

b) RP-1 Sampling Stations. This function supplies air samples to the RP-1 detection unit. It consists of eight sensing heads—one on Level 1, three on Level 7, and four on Level 8—in the missile enclosure area of the silo. It also includes the interconnecting piping from the sensing heads to the detection unit. The detection unit can sample air from only one sensing head at a time.

c) Signal Indicator Lamps. This function provides an indication to personnel that the concentration of RP-1 vapor in the missile enclosure area is excessive and that a hazardous condition exists. Mounted on Level 6 (Work Platform 3), it consists of an amber light that flashes on and off when 20 percent LEL is reached and a red light that flashes on and off when 40 percent LEL is reached. This and RFB 8.7 d) are controlled automatically from the detection unit.

d) Signal Horn. This function warns personnel that the concentration of RP-1 vapor in the missile enclosure area is excessive and that a hazardous condition exists. It consists of a horn mounted on Level 6 that sounds when either 20 or 40 percent LEL is reached.

RFB 8.8 Oxygen Detection System. (Figures A-1, 7-8) This function samples silo air for an excess or deficiency of oxygen. Sampling stations are located on Levels 7 and 8 and the silo floor. Each station in turn is sampled for 30 seconds. The samples are drawn by a vacuum pump to the detector unit for analysis. A high rating, over 25 percent, or a low rating, under 19 percent, will sound an alarm, show an indication on the Facility Remote Control panel, and control certain of the air conditioning equipment. Every four hours the units go through an automatic calibration cycle utilizing external sources of oxygen and nitrogen. A system failure would energize the alarm or cabinet panel lights, depending upon the type of failure.

a) Sampling Stations. This function consists of eight sampling stations.

b) Sampling Stations. This function consists of two sampling stations.

c) Oxygen Detector Unit. This function consists of the cabinet and all the electrical and mechanical equipment in it.

d) Oxygen Detector Unit. This function consists of the cabinet and all the electrical and mechanical equipment in it.

e) Alarms. This function consists of a warning horn and flashing light

f) Scan Gas. This function consists of an oxygen cylinder.

g) Zero Gas. This function consists of a nitrogen cylinder.

h) Lines. This function consists of all interconnecting lines and valves in the oxygen detection system.

RFB 8.9 Diesel Fuel Vapor Subsystem. (Figure A-1, L-8)

RFB 8.9.1 Diesel Fuel Vapor Detection Unit. (Figures A-1, L-8) This function consists of a detection unit which continuously takes in air from the diesel engine area on silo Level 5 and analyzes it by means of a combustion cell for diesel fuel vapor. When the diesel fuel vapor content of the air reaches 10 percent of the lower explosive limit (LEL), an amber warning light on the unit is turned on and a warning horn, also on the unit, sounds. When the diesel fuel vapor content of the air reaches 20 percent LEL, a red alarm lamp on the unit lights, the warning horn sounds, LCC visual and audible alarms are energized (on the Facilities Remote Control panel), the silo lower supply fan is de-energized, and silo air dampers VD-21, VD-30, VD-31 and VD-32 are actuated. The detection unit consists of a vacuum pump, control unit, and monitor unit. It is located on silo Level 7

RFB 8.9.2 Sensing Head. (Figures A-1, L-8) This fuction supplies air to the diesel fuel vapor detection unit for analysis. It consists of a sensing head mounted in the diesel engine area on Level 5. It also includes the copper tubing connecting the sampling head on Level 5 to the detection unit on Level 7.

RFB 8.10 Blast Protection System. (Figures A-1, J-8) Except for the GO_2 exhaust all blast closures are normally open, and are controlled by a fail-safe system which will close the valves in case of failure. At the operational bases the system is controlled by a blast detection system. At OSTF-2 this detection system is replaced by a blast simulation button located on the Facilities Remote Control panel. Depressing this button will shut all closures. When closed, the closures protect the silo and the LCC against overpressure.

a) GO_2 Exhaust Blast Closure. This function is a normally closed valve or cover on the GO_2 exhaust vent. It is opened for LO_2 loading and certain purging operations.

b) Silo No. 1 Air Exhaust Blast Closure. This function is a valve or cover on the silo No. 1 air exhaust vent. It consists of a 42-inch quick closing poppet valve, a three-way solenoid valve, a check valve to prevent return flow, and all piping downstream of the flex hose assembly together with the necessary hardware.

c) Silo No. 2 Air Exhaust Blast Closure. Same as RFB 8.10 b) except for silo No. 2 air exhaust.

d) Silo No. 1 Air Intake Blast Closure. Same as RFB 8.10 b) except for silo No. 1 air intake.

e) Silo No. 2 Air Intake Blast Closure. Same as RFB 8.10 b) except for silo No. 2 air intake.

f) LCC Air Intake Blast Closure. This function is a valve or cover on the LCC air intake. It consists of a 16-inch quick closing valve, a solenoid exhaust valve, a three-way solenoid valve, and an air reservoir together with the necessary piping and hardware downstream of check valve V-104. Check valve V-104 is included in RFB 8.8.9.

g) LCC Air Exhaust Blast Closure. Same as RFB 8.10 f) except for air exhaust.

h) LCC Sewer Vent Blast Closure. This function is a valve or cover on the LCC sewer vent. It consists of a 3-inch spring loaded valve, and the necessary piping and hardware downstream of, but not including, solenoid valve V-505.

j) LCC Air Exhaust Blast Closure No. 2. This function is a valve or cover on the No. 2 LCC air exhaust vent (not at OSTF-2).

k) LCC Air Support Spring No. 1. This function is an air suspension spring that, together with three others, supports the LCC and protects it from excessive vibration in case of a nearby bomb blast. It consists of a Boeing supplied air cylinder assembly and the necessary piping and hardware downstream of a flexible hose. The flexible hose is included in RFB 8. 20. 10.

m) Level Detection and Control No. 2. Same as for RFB 8. 10 u) except No. 2.

n) LCC Air Support Spring No. 2. Same as for RFB 8. 10 k).

p) Level Detection and Control No. 3. Same as for RFB 8. 10 u).

r) LCC Air Support Spring No. 3. Same as for RFB 8. 10 k).

s) Level Detection and Control No. 4. Same as for RFB 8. 10 u). except No. 4.

t) LCC Air Support Spring No. 4. Same as for RFB 8. 10.

u) Level Detection and Control No. 1. This function controls the LCC No. 1 support spring to keep LCC level. It consists of a Minneapolis-Honeywell level control and detection assembly.

v) LCC Escape Hatch. This function provides a means of emergency escape in case the personnel entry tunnel becomes blocked. It consists of a lug secured. 0. 25-inch, steel dished hatch cover and its clamps and limit switches located in the LCC roof.

w) LCC Personnel Door. This function seals the LCC from blast overpressure. It consists of a door, its fasteners, and limit switches located in the personnel entry tunnel.

RFB 8. 11 Instrument Air System. (Figures A-1, L-7).

a) Instrument Air Prefab. This function consists of the instrument air prefab which comprises all lines, valves, regulators, hardware, stubups, and miscellaneous equipment, including instrument panel, that are physically a part of the prefab, excluding the electrical portion. The unit contains two reciprocating, four-stage air compressors with built-in interstage cooler and external after cooler. Each compresor has a capacity of 15 scfm at 1500 psig

when operating at sea level suction conditions. The air receiver (or storage tank) is a carbon steel spherical tank designed for 1600 psig maximum working pressure; it has a volume of 65 cubic feet. The function of the instrument air prefab is to compress, dry, filter, and store air for control use in the silo. The prefab supplies compressed air for the pneumatic distribution unit at 300 psig.

b) Instrument Function—Pressurization Prefab. This function makes up the instrument air portion of the pressurization prefab and comprises the instrument panel, all valves, instrumentation lines, stubups, and hardware in the pressurization prefab that pertain to this function. The instrument air function is to send controlling air to the cool-down pressure controller, transfer pressure controller PC-2, transfer pressure controller PC-3, liquid level indicators, and various other control valves and regulators in the pressurization prefab.

c) Instrument Air Function (LO_2 Control Prefab). This function consists of the instrument air portion of the control prefab which comprises all valves, regulators, lines, and hardware that pertain to the instrument air function of the LO_2 fill prefab. The function of the instrument air portion of the LO_2 control prefab is to control the LO_2 valves in the prefab.

d) Instrument Air Function (LO_2 Fill Prefab). This function consists of the instrument air portion of the LO_2 fill prefab which comprises all valves, regulators, lines, and hardware that pertain to the instrument air function of all LO_2 fill prefab. The function of the instrument air portion of the LO_2 fill prefab is to control LO_2 valves in the prefab.

e) Instrument Air Function (LN_2 Prefab). This function consists of the instrument air portion of the LN_2 prefab which comprises all valves, regulators, lines, and hardware that pertain to the LN_2 prefab. This function also includes the instrument panel. The function of the instrument air portion of the LN_2 prefab is to control the valves in the LN_2 prefab.

f) Instrument Air Function—Pneumatic Distribution Unit. This RFB consists of the instrument air portion of the PDU and comprises all valves, regulators, lines, and hardware that pertain to the instrument air function of PDU. It also includes the instrument panel. The function of this RFB is to provide instrument air for valve control within the PDU and to distribute instrument air to all ground functions requiring its use.

g) Instrument Air Function—Pressurization Control Unit. This RFB consists of the instrument air portion of the PCU and comprises all valves, regulators, lines and hardware that pertain to the instrument air function of the PCU. This RFB also includes the instrument panel. The function of the instrument portion of the PCU is to control valves within the unit.

h) Instrument Air Function (Interconnecting Lines). This RFB consists of all interconnecting lines in the instrument air system, as follows:

1) Line APD (Instrument Air Prefab to PDU). This line interfaces with instrument air prefab stubup APD on one end, the other end of the line interfaces with PDU stubup APD.

2) Line APU(PDU to PCU). This line interfaces with PDU stubup APU and PCU stubup APU. The function of line APU is to carry instrument air from the PDU to the PCU.

3) Line AHE. This line runs from the pneumatic distribution unit to the pressurization prefab. It consists of a 0.5-inch line section, a 0.5 to 0.375-inch flange, and a 0.375-inch line section. The function of this line is to carry instrument air to the pressurization prefab from the PDU. This line ties into these branches:

- Branch 1 (Line AHE to Three Vacuum Pumps). This portion of line AHE tees off from line AHE 1/2 and forms a manifold feeding the three vacuum pump control valves.

- Each line of the manifold contains a 0.5 to 0.375-inch line section, a regulator, and a solenoid valve. The function of this branch is to carry instrument air to the valves that control vacuum pump operation.

- Branch 2 (Line AHE to LN_2 Prefab). This portion of line AHE branches off from line AHE 1/2 and runs to the LN_2 prefab. It consists of a 0.5-inch line section, 0.5 to 0.075-inch flange, and a 0.375-inch line section. The function of this line is to carry instrument air from the PDU to the LN_2 prefab.

- Branch 3 (Line AHE LO_2 Control Prefab). This portion of line AHE branches off from line AHE 1/2 and runs to LO_2 control prefab. This line consists of a 0.5-inch line section. 0.5 to 0.375-inch flange, and a 0.375-inch line section.

The function of this line is to carry instrument air from the PDU to the LO_2 fill prefab.

4) Line C101-3/4 (LO_2 Control Prefab to LO_2 Fill Prefab). This line interfaces with LO_2 control prefab stubup C-101 and LO_2 fill prefab stubup C-200. The function of this line is to carry control air from the LO_2 control prefab to the LO_2 fill prefab.

j) Interconnecting Lines. This function supplies compressed air to pressurize the hydro-pneumatic utility water supply tank, TK-80. It consists of the line 412-3/4 inch to the utility water tank and associated valves and hardware.

k) Interconnecting Lines. This function supplies compresssed air to the No. 1 diesel air starting system. It consists of line 406-1/2 inch from line 405-3/4 inch to the air receiver tank, the tank itself, and line 404-1 inch from the tank to the No. 1 diesel engine starting system. It also includes associated lines, valves and hardware.

m) Diesel Starting System. This function consists of compressed air lines that supply the diesel for starting purposes. It interfaces with RFB 8.21.10 at a flex connection on line 404-1 inch between the air receiving tank and the diesel generator. The flex connection belongs to RFB 8.11 k).

n) Interconnecting Lines. This function supplies compressed air to the two silo air intake blast closures, to the two silo air exhaust blast closures, to the safety platform lift mechanism, and to the silo GO_2 purge exhaust blast closures. It consists of:

1) Line 405-3/4 inch from the instrument air prefab to tee with lines 408-1/2 inch and 409-1/2 inch; lines 408-1/2 inch and 409-1/2 inch to air intakes 1 and 2 respectively, interfacing at the flexible hoses with RFB 8.2.

2) Line 407-3/4 inch from line 405-3/4 inch to tee with lines 410-1/2 inch and 411-1/2 inch; lines 410-1/2 inch to air exhausts 1 and 2 respectively, interfacing at the flexible hoses with RFB 8.2.2.

3) Line 405-3/4 inch that goes to the safety platform lift mechanism where it interfaces with a 12-gallon hydraulic accumulator.

4) The air line to the GO_2 purge exhaust blast closure.

5) This function includes all associated lines, valves, and hardware.

p) Interconnecting Lines. This function supplies compressed air to the LCC air receiver tank. It consists of line 400-3/8 inch from the instrument air prefab to line 402-1/2 inch, line 402-1/4 inch, line 402-3/4 inch, line 402-3/4 inch to the air receiver tank, line 401-1/4 inch, line 403-1/4 inch, and associated lines, valves, and hardware.

r) Air Receiver Tank. The air receiver tank is a compressed air reservoir which supplies air to the LCC spring supports, blast closures, and to the air conditioning system. It consists of the tank and the associated lines, valves, and hardware. RFB 8.21.14 interfaces with the LCC air conditioning system, but does not include humidistat H and roomstat T_1.

s) Interconnecting Lines. This function supplies compressed air from the LCC air receiver tank to the four LCC air cylinder spring supports. It consists of line 1000-1/2 inch from the tank to line 1001-1/2 inch, line 1001-1/2inch which branches off to the four air cylinder spring supports, and associated lines, valves, and hardware. It interfaces at a flexible hose with RFBs 8.20.10, 8.20.12, 8.20.14, and 8.20.16. The hoses are included in the RFBs 8.20.10, 8.20.12, 8.20.14 and 8.20.16.

t) Interconnecting Lines. This function supplies compressed air to the LCC exhaust vent blast closure, intake blast closure, and sewer vent blast closure. It consists of line 1003-1/2 inch from line 1000-1/2 inch to line 1004-1/2 inch, line 1004-1/2 inch to the LCC exhaust vent blast closure, line 1004-1/2 inch to the intake vent blast closure, line 1004-1/2 inch to the sewer vent blast closure, and associated lines, valves, and hardware.

1) It interfaces with RFB 8.20.7 at check valve V-104 which is included in RFB 8.21.16.

2) It interfaces with RFB 8.20.6 at check valve V-104 which is included in RFB 8.21.16.

3) It interfaces with RFB 8.20.8 at check valve V-104 which is included in RFB 8.21.16.

RFB 8.12 <u>Diesel Fuel Oil Subsystem.</u> (Figures A-1, K-7) A soft storage tank of 15,300 gallon capacity is located below ground outside the silo. A gravity line carries the fuel oil to a day storage tank located on Level 5. From there the fuel is gravity fed to the diesel. Two return lines from the diesel to the day storage tank are provided, one from the manifold and the other from the drip return pump.

RFB 8.12.1 <u>Soft Storage.</u> This block consists of the soft storage tank and its fill and vent lines.

RFB 8.12.2 <u>Day Storage.</u> This block consists of the day storage tank, its liquid level gauge, and its drain and vent lines.

RFB 8.12.3 <u>Lines and Valves</u>. This block consists of all interconnecting lines and valves in the fuel oil subsystem except those specifically called out in RFB 8.5.1, and those that come as parts of the diesel engine.

SYSTEM 9.0—HEATING, VENTILATING, AND AIR CONDITIONING SYSTEM

RFB 9.1 Silo Air Conditioning Supply. (Fig A-1, M-7) The silo air conditioning supply system supplies the silo spaces with fresh, washed, dehumidified air. Air is drawn in through blast closures to the dust collectors where it is washed and then ducted to the diesel rooms. Some of it is pulled off and used for ventilating level 1. Some of it is vented from the diesel room to level 5 (level 6 at operational bases). Some of the air is used by diesel (level 2 at operational bases). The rest of the air is ducted from the diesel room to level 8 for distribution. Water for the washing cycle is recirculated by pumps through a sand settling tank for clarification. A heater is used in the air inlet at some of the operational bases to prevent freezing in the dust collectors during cold weather.

RFB 9.1.1 Dust Collector and Ducting. This block includes all the ducting from the blast closures to the dust collector, the dust collector, and the ducting from the collector to the diesel room.

RFB 9.1.2 Dust Collector and Ducting. This block consists of the dust collector and the ducting from the intake plenum to the dust collector.

RFB 9.1.3 Lower Silo Blower and Ducting. This block consists of the ducting from the diesel room to the blower, the blower, and the ducting from the blower to and including the registers on level 8.

RFB 9.1.4 Water Storage Tank. This block consists of the water storage tank, vent line, overflow line, level gage, and level control.

RFB 9.1.5 Sand Settling Tank. This block consists of the sand settling tank, drain line, and air vent.

RFB 9.1.6 Pump. This block consists of the pump and motor.

RFB 9.1.7 Water Lines and Valves. This block consists of all the lines and piping associated with the air wash system.

RFB 9.2 Silo Air Conditioning Exhaust. (Figures A-1, N-7) This system exhausts the used air from the silo. Most of the air is picked up at level 2

by the main exhaust fan and dumped outside through two blast closures. Heat is extracted from the diesel exhaust by heat exchanger silencers. The exhaust is then put into the system at the mouth of one of the blast closures. The missile enclosure exhaust dumps in down stream of the main exhaust fan. A purge line leads from the lower diesel room to the main exhaust fan to carry off excess diesel fuel fumes. During blast and missile launch the blast closures are closed and the exhaust air is routed to the silo air conditioning supply system. During cold weather some air is recirculated to the air supply system.

RFB 9.3 Missile Enclosure Air Conditioning System. (Fig A-1, N-7) The purpose of this system is to maintain the missile enclosure at 70°F and 65 percent relative humidity maximum. Most of the air is recirculated through a fan coil unit containing both cooling and heating coils. The normal exhaust fan maintains a slightly negative pressure in the enclosure. Make-up air comes from the main silo supply through a cooling coil not at OSTF-2. The enclosure is purged of high RP-1 concentrations by the purge supply and the purge exhaust fans. For high GO_2 concentrations the enclosure is purged by the purge supply fan and the GO_2 exhaust fan.

RFB 9.3.1 Fan Coil Unit and Ducting. This block consists of ducting from the missile enclosure to the fan coil unit, the fan coil unit, and ducting from the fan coil unit to the missile enclosure.

RFB 9.3.2 Purge Supply Fan. This block consists of the purge supply fan unit.

RFB 9.3.3 Normal Exhaust Fan and Ducting. This block consists of ducting from the missile enclosure to the normal exhaust fan, the normal exhaust fan, and ducting from the fan to the main silo exhaust system.

RFB 9.4 Silo Electronics Air Conditioning. (Fig A-1, O-7) This system located on level 3 supplies dehumidified air at 70°F and 65 percent relative humidity to the logic units on level 3, the responder units on level 3, the Arma units on level 3, and the alignment station at level 7. Under normal operation most of the air is recirculated. In event of cooling water failure the system will use 100 percent make-up air. For conditions of high humidity the air is overcooled to rid it of some water and then reheated by the reheater.

RFB 9.4.1 Fan Coil Unit and Ducting. This block consists of all ducting from the electronic cabinets to the fan coil unit, the fan coil unit, and the ducting from the fan coil unit to the reheater.

RFB 9.4.2 Reheater and Ducting. This block consists of the reheater, the ducting from the reheater to the electronic cabinets, and the ducting to the alignment station.

RFB 9.5 Missile Air Conditioning. The missile air conditioning requirements are supplied by three systems. The thrust section heating system supplies hot air at $140^{\circ}F$ to $175^{\circ}F$ to the missile thrust section. The air comes from outside the missile enclosure and is exhausted inside the enclosure. The system comes on at the start of countdown. The pod air conditioning unit supplies dehumidified, refrigerated air to the missile pods and an Arma amplifier located in the umbilical J-box. Air from the dehumidifier section is exhausted to the missile enclosure exhaust system. (Exhaust from the LO_2 boiloff valve during LO_2 loading is exhausted outside the silo by the GO_2 exhaust fan.)

RFB 9.5.1 Pod Air Conditioning Unit, Lines, and Ducting. (Fig A-1, P-7) This block consists of the pod air conditioning unit, ducting to the missile and the Arma amplifier, the dehumidifier ducting to RFB 9.3.3, and the condensate piping to the silo floor.

RFB 9.5.2 Thrust Section Heating Blower. (Fig A-1, P-7) This block consists of ducting to the blower, and the ducting from the blower to the heaters.

RFB 9.5.3 Heaters and Ducting. (Fig A-1, P-7) This block consists of the heaters and the ducting from the heaters to the missile thrust section.

RFB 9.5.4 GO_2 Exhaust Fan and Ducting. (Fig A-1, N-7) This block consists of the ducting from the vicinity of the LO_2 boiloff valve to the fan, the fan, and the ducting from the fan to the blast closure.

RFB 9.5.5 Duct Retraction Mechanism. (Fig A-1, O-7) This block consists of all the hardware that makes up the retraction mechanism.

RFB 9.6 Launch Control Center Air Conditioning. (Fig A-1, N-7) This system supplies the LCC with fresh flitered air at 70°F in winter and 80°F (70% max. R.H.) in summer. Air is brought in from outside through a blast closure and a chemical, biological and radiological filter. It is then mixed with recirculated air, run through a dust filter, heated or cooled, and distributed. A fan exhausts air from the toilet and battery room through a blast closure to the outside. Some air is also expelled through the blast door. During blast or firing conditions all air is recirculated. At operational sites there is a fan coil unit located in the communications room to remove heat from extra electronic gear.

RFB 9.6.1 CBR Filter and Ducting. This block consists of the CBR filter and the ducting from the blast closure to the filter.

RFB 9.6.2 Dust Filter and Ducting. This block includes the dust filter, the ducting from the CBR filters to the dust filter, and the return air ducting from level 2.

RFB 9.6.3 Supply Fan and Ducting. This block consists of the supply fan and the ducting from the dust filter to the fan.

RFB 9.6.4 Cooling Coil and Ducting. This block consists of the cooling coil and the ducting from the supply fan to the coil.

RFB 9.6.5 Heating Coil and Ducting. This block consists of the heating coil, ducting from the cooling coil to the heating coil, and the distribution ducting from the heating coil to the various spaces.

RFB 9.7 Pneumatic Control System. (Fig A-1, M-7) The Heating Ventilating and Air Conditioning pneumatic control supply supplies control air to System 9 volume dampers and System 8 water lines that feed System 9. The air is supplied by compressor and controlled by solenoid operated valves located on the electro-pneumatic control panel.

RFB 9.7.1 Air Compressor. This block includes the compressor and motor and associated receiver, dryer, valves, etc., plus the tubing to RFB 9.7.2.

RFB 9.7.2 Electro-Pneumatic Valve Control Panel. This block includes all the instruments located on the panel, with its associated tubing, and the tubing to each controlled unit.

RFB 9.8 Missile Pod Cooling System. (Fig A-1, P-8)

a) Forward Pod Cooling. The cooling system for the missile forward pod cooling consists simply of a light alloy, rectangular section supply duct dividing into two similar ducts which connect with two circular tubes having plugged ends. A series of small holes drilled in these tubes directs streams of cool air on the airborne electronic equipment.

b) Aft Pod (AIG) Cooling. This cooling system consists of a framework of piping designed to supply cooling air to the inertial guidance equipment. Small holes in the piping direct air streams on to the equipment units.

c) Rate Gyro Cooling. A 3/8-inch-diameter aluminum tube connected to the forward pod cooling system carries cooling air to the rate gyro mounted on the outside of the oxidizer tank and in the wiring tunnel envelope. Small holes in the tube distribute cooling air around the rate gyro unit.

d) Pod B-1 Cooling. Similar to pod B-2 cooling, this system consists of light alloy tubes shaped and drilled to distribute cooling air over the special equipment in the pod.

RFB 9.9 Thrust Section Heating. (Fig A-1, P-8)

a) Thrust Section Heating. The only installation on the missile for this system is a short tube designed to connect with the ground ducting. Warm air, fed through this ducting is diffused into the thrust section area directly from the short tube.

SYSTEM 10.0—MISSILE LIFT SYSTEM

The missile lift system includes the basic support structure (excluding crib), hydraulic, pneumatic, and electric motors, and mechanical equipment associated with automatically or manually sequencing operations of the launch platform (manual control of the equipment is provided for maintenance purposes).

RFB 10.1 Hydraulic Pumping Unit (Silo Lift System). (Fig A-1, R-5) This system provides the distribution and necessary fluid pressure and flow required for the operation of all hydraulic components within the missile lifting system. This sub-system includes the following components:

RFB 10.1.1 Gaseous Nitrogen (GN_2) Tanks. Included are the five individual tanks and piping and valves leading to the accumulators. The GN_2 tanks are resupplied from storage tanks through the PDU. They supply nitrogen gas to the accumulators on demand signals from the logic unit and from the local control panel.

RFB 10.1.2 Hydraulic Reservoir. Included are the 324-gallon tank, filters, standby accumulator, piping and valve control panel.

RFB 10.1.3 Distribution Accumulator System. Included are two accumulators and valves, piping, fittings, umbilical loops, and flexible hose leading to the respective manifolds. The accumulators are of the floating piston type.

RFB 10.1.4 Low Pressure Hydraulic Pump. Included are a 4.9 gpm, 210 psig pump, 1-hp electric drive motor, and valves, piping, and fittings leading to the accumulators. This pump maintains 100 - 210 psig standby pressure in the hydraulic system.

RFB 10.1.5 Silo Door Accumulators. Included are six accumulators, and valves, piping, and fittings leading to the silo door manifolds. They provide the necessary hydraulic power to open the silo doors, and were devised to lessen electrical power demands during critical commit sequence.

RFB 10. 1. 6 <u>High Pressure Hydraulic Pump</u>. Included are a 19. 8 gpm, 3000 psig pump, 40-hp electric drive motor, and valves, and piping leading to the accumulators plus silo door down-cycling valves and piping. The pump provides hydraulic power for down cycling of the doors, for recharging the accumulators with fluid, and returns nitrogen to the vent valves.

RFB 10. 1. 7 <u>Silo Door Manifold (One for each door)</u>. Included are two solenoid valves and the piping and fittings necessary to distribute hydraulic power from the accumulators (or pump RFB 10. 1. 6) to the open or close side of the door actuating cylinder, and to the extend side of the breakaway cylinders.

RFB 10. 1. 8 <u>Crib Lock Manifold.</u> Included are two valves and piping and fittings necessary to distribute hydraulic power from the accumulators (or pump RFB 10. 1. 6) to the horizontal and vertical crib lock actuators.

RFB 10. 1. 9 <u>Launch Platform Lock Manifold</u>. Included are two valves (one for wedge locks and one for main locks) and the piping and fittings necessary to distribute hydraulic power from the accumulators (or pump RFB 10. 1. 6) to the platform locks (RFB 10. 3. 1).

RFB 10. 1. 10 <u>Miscellaneous Manifold</u>. Included are two valves (one for launcher platform breaks, and one for the drive control coupling) and the piping and fittings necessary to distribute hydraulic power from the accumulators (or pump RFB 10. 1. 6) to the launch platform drive system clutch assembly (RFB 10. 2. 3) and brake assembly (RFB 10. 2. 4).

RFB 10. 1. 11 <u>Local Control Panel Assembly</u>. This assembly contains valves, pressure gauges, pressure switches, and associated piping necessary for manual control of the hydraulic and accumulator pressurization systems.

RFB 10. 2 <u>Launch Platform Drive System</u> (Fig A-1, R-5) This drive system provides the silo-type sites with equipment capable of elevating and/or lowering the launch platform and missile to and from ground level. The equipment operation is sequenced through logic unit, but for maintenance purposes it can be operated by manual control.

RFB 10.2.1 Motors and Tachometer Generators. Included are two identical motors (each 125 hp, 480 vac), and two tachometer generators. One motor is used in conjunction with the main reduction gear (RFB 10.2.2), for high-speed hoisting, and the other motor is used in conjunction with the auxiliary reduction gear for low-speed hoisting. Motor speeds are controlled by a tachometer feedback system. Various speed commands are initiated by countdown logic, or by the control station manual operating level.

RFB 10.2.2 Main Reduction Gear. Included are the entire assembly, the mating coupling connection with the high-speed motor, and flexible coupling, shafts, and drive gears associated with driving the traction sheaves (RFB 10.3.8).

RFB 10.2.3 Clutch Assembly. Included are the entire assembly, the mating coupling with auxiliary reduction gear, the mating coupling with main reduction gear, hydraulic actuator, support frame, and attaching hardware. The clutch provides a union between the auxiliary and main reduction gears (RFB 10.2.2).

RFB 10.2.4 Brake Assembly. Included are the mechanical assembly, four hydraulic brake actuators, and equipment required to attach the brake assembly to the main reduction gear. The brake is 4 fail-safe design in that springs will apply the brakes if hydraulic pressure is lost.

RFB 10.2.5 Tension Equalizer Assembly. Included are the "teeter-bar" assembly and related attachment hardware for ten strands of wire rope and bracketry. It provides an anchor point for one end of the wire ropes, and equalizes the tension between two sets of ropes incorporating five strands each.

RFB 10.2.6 Wire Rope Assembly. Included are two five-strand wire ropes. These ropes are anchored at one end to the tension equalizer, and at the other to the counterweights.

RFB 10.2.7 Traction Sheaves. Included are two cylindrical drums, housing, shaft, and associated attaching equipment. They are driven by the motors through the reduction gears, and impart motion to the launch platform through the wire ropes.

RFB 10.2.8 Counterweight Assembly. Included are the counterweight, wire rope attaching bracketry, sheaves and attaching bracketry, and the guide rail shoes. The counterweights are necessary to counterbalance the weight of the launch platform.

RFB 10.2.9 Counterweight Guide Rails. Included are several sections of rails and crib attaching bracketry. The guide rails prevent lateral movement of the counterweights.

RFB 10.3 Launch Platform Assembly. (Fig A-1, R-5) This assembly provides structural support for both the missile and the AGE required to maintain missile systems during the rise sequence until missile rise-off.

RFB 10.3.1 Launch Platform Lock Actuators. Included are four hydraulically operated locks, wedge locks, up-lock strikers, and valves to actuate the locks. Also included are the attaching bracketry and mechanical linkage. The locks are used to lock the platform to the silo cap when the platform is fully raised, and to the crib when fully lowered.

RFB 10.3.2 Launch Platform. Constructed of steel beams and plates, it includes three equipment levels to accommodate the associated AGE.

RFB 10.3.3 Flame Deflector. This is an integral part of the platform, located on the second level.

RFB 10.3.4 Idler Sheaves. Located under the fourth level, this includes four sheaves, supporting bracketry, and attaching equipment. They support the launch platform when it is in motion by mating with the wire rope assembly.

RFB 10.3.5 Guide Rollers. Included are four sets of large guide rollers and one set of small guide rollers, and the associated bracketry to attach them to the launch platform. These serve as guides and stabilizers when the launch platform is in motion.

RFB 10.3.6 Guide Rails. Included are two large rails, one small rail, and attaching bracketry. The guide rails, in conjunction with the guide rollers, align and stabilize the launch platform when it is in motion.

RFB 10. 3. 7 Launcher. Included are the horizontal structural members, supporting tubular tripod assembly, and attaching bracketry to the top of the launch platform. The launcher supports and maintains the missile in the vertical position.

RFB 10. 3. 8 Rise-off Panels. Included are two panels that accommodate the rise-off disconnects, mechanical alignment linkage, and attaching bracketry to the launcher.

RFB 10. 3. 9 Launch Platform Disconnect Panels. Included are the hot panel, cold panel, and the NCU panel. These panels support and align the launch platform disconnects.

RFB 10. 4 Door Closure System. (Fig A-1, S-5) The door closure system provides a means of opening and closing the two concrete reinforced silo doors. The system is designed to open the doors within 45 seconds, for both tactical and checkout operations.

RFB 10. 4. 1 Door Actuators. Included are two large hydraulic cylinders, valves, and mechanical linkage. The actuators are extended by hydraulic/pneumatic pressure, and retracted by hydraulic pressure.

RFB 10. 4. 2 Break-Away Actuators. Included are four hydraulically operated cylinders, valves, and piping. The actuators provide initial break-away lift for the silo doors.

RFB 10. 4. 3 Door Actuator Brackets. Included are the attaching brackets to the silo caps, attaching brackets to the doors, and the bracket attachment hardware. The brackets provide attachments for each end of the actuators.

RFB 10. 5 Crib Suspension and Lock System. (Fig A-1, R-6) The crib suspension and lock system provides vertical and horizontal isolation from ground shock for the crib, missile, and all missile support equipment mounted on the crib and launch platform.

RFB 10. 5. 1 Vertical Spring Capsule Locks. Included are four hydraulically operated locks, a locking arm, bearing roller, valves, piping,

mounting bracketry, and associated attaching equipment. These locks, when engaged with the shock struts, restrict the crib motion.

RFB 10. 5. 2 Horizontal Crib to Silo Locks. Included are three hydraulic actuating cylinders, bearing plates, striker plates, piping, fittings, and attaching bracketry. The purpose of these locks is twofold; to restrict motion of the crib and to align the launch platform with the silo cap opening.

RFB 10. 5. 3 Spring Bay Assembly. Included are the outer, inner and intermediate coil springs. These springs are assembled in clusters around the shock struts and tierods.

RFB 10. 5. 4 Shock Struts and Wall Brackets. Included are the eight shock struts, four crib brackets, spacers, flanges, large structural beams, plates, and all associated attaching equipment. The shock struts including the spring assemblies are suspended in pairs from the silo structure and support the crib, launch platform, missile and supporting AGE.

RFB 10. 5. 5 Horizontal Crib to Silo Dampers. Included are the four fluid/mechanical dampers, and all associated attachment brackets and equipment. They provide damping of any crib structure motion by reacting against the silo wall.

RFB 10. 6 Collimator Accessories. (Fig A-1, S-6) The collimator accessories provide a line of sight between the missile inertial guidance equipment and the collimator that is mounted on the silo wall.

RFB 10. 6. 1 Sight Tube Assembly. Included are two sections of tubing, pivot point assembly, and tube support and attaching equipment.

RFB 10. 6. 2 Sight Tube Retracting Mechanism. Included are a counterweight assembly and attaching fittings to the pivot assembly. This mechanism retracts the tube away from the missile during initial launch platform rise.

SYSTEM 12.0—LAUNCH CONTROL SYSTEM

RFB 12.1 Launch Control Console. (Fig A-1, D-4) The launch control console monitors the state of readiness of the missile and AGE during countdown, commit, and hold at a safe point. The console provides controls for starting countdown, commit sequence, placing the missile in hold, and initiates an abort if a malfunction occurs. In addition, the console provides manual emergency controls for missile pressurization control, a communication control patch, a malfunction patch, and controls for target selection and range correction.

RFB 12.2 Relay Logic Units. The relay logic units house, provide ventilation for, and contain interconnecting wires for all the logic subsystems.

RFB 12.2.1 AIG and Autopilot Logic

RFB 12.2.1.1 Autopilot Logic. (Fig A-1, F-2) The autopilot control logic provides sequential control and monitoring of the airborne autopilot system.

RFB 12.2.1.2 Guidance Control Logic. (Fig A-1, F-3) The guidance system monitors the autopilot, missile power, countdown, and re-entry vehicle signals, and controls the guidance countdown group.

RFB 12.2.2 Re-entry Vehicle Control Logic. (Fig A-1, F-3) The re-entry vehicle control logic provides sequential control and monitors the operation and status of the re-entry, pre-launch monitor and the missile re-entry vehicle system.

RFB 12.2.3 Engine Control Logic. (Fig A-1, F-4) The engine control logic initiates the sequencing of the engine control valves and the firing of the booster and sustainer gas generator's initiators, and igniters during countdown. It also controls the engine cut-off valves on a commit stop command. During standby, the unit is used to check continuity of the booster and sustainer gas generators, initiators, igniter, and associated circuitry.

RFB 12.2.4 Countdown Control Logic. (Fig A-1, E-4) The countdown control logic provides sequential control and monitoring of all control logics.

RFB 12.2.5 Missile Ground Power Control Logic. (Fig A-1, F-4) The missile ground power control logic controls the application of 28-vdc and 115-vac, 400-cps ground power to the missile, starts, and monitors missile inverter voltage and frequency, activates the missile battery, and transfers missile electrical load to internal power during countdown. It also supplies ground power to the autopilot coarse heaters and missile guidance system during standby.

RFB 12.2.6 Pneumatic and Hydraulic Logics

RFB 12.2.6.1 Hydraulic Control Logic. (Fig A-1, F-5) The hydraulic control logic activates the hydraulic pumping unit, monitors operating pressures, valve positions, and initiates the hydraulic oil evacuate operations during countdown.

RFB 12.2.6.2 Pressurization Control Logic. (Fig A-1, F-5) The pressurization control logic controls the pressurization control unit which regulates the pressure in the missile LO_2 and fuel tanks during standby. During a countdown, the pneumatic chassis controls and monitors the operation of the PCU, missile pod air-conditioning unit, and the helium charge unit.

RFB 12.2.6.3 LN_2/He Tanking Control Logic. (Fig A-1, F-5) The LN_2/He tanking control logic controls and monitors LN_2 loading into the missile helium bottle shrouds, helium loading into the missile helium bottles during countdown, and LN_2 and helium venting during return to standby condition.

RFB 12.2.7 Propellant Loading Logic

RFB 12.2.7.1 Fuel Tanking Control Logic. (Fig A-1, F-6) The fuel tanking control logic monitors the status of automatic valves, fuel temperature, fuel drainage condition, and fuel level tank condition.

RFB 12.2.7.2 LO_2 Tanking Control Logic. (Fig A-1, F-6) The LO_2 tanking control logic sequences the transfer of LO_2 from the storage facility to the missile LO_2 tank during countdown.

RFB 12.2.7.3 Propellant Level Control Logic. (Fig A-1, F-6) The propellant level control logic controls the rate of flow of LO_2, LO_2 topping, and cutoff during countdown. It also exercises partial control of the propellant loading and drainage process during hold, commit, and abort conditions.

RFB 12.2.8 Facility Control Logic. (Fig A-1, F-7) The facility control logic controls and monitors certain facility items such as thrust section heater blowers, LO_2 vents and dampers, and blast covers during coutdown.

RFB 12.2.9 Missile Lifting Platform Control Logic. (Fig A-1, F-7) The missile lifting platform control logic controls and monitors the AMF logic cabinet signals.

RFB 12.3 Launch Signal Responder Units. The launch signal responder units house, provide ventilation, and contain interconnecting wires for all the responder subsystems.

RFB 12.3.1 AIG and Autopilot Responders

RFB 12.3.1.1 Autopilot Responder. (Fig A-1, H-2) The autopilot responder simulates the function of the missile autopilot equipment for the purpose of checking the operation of the autopilot control logic and launch officers console.

RFB 12.3.1.2 Guidance Responder. (Fig A-1, H-2) The guidance responder simulates the function of the countdown group and missile guidance system for the purpose of checking the operation of the guidance control logic and the launch officers console.

RFB 12.3.2 Re-entry Vehicle Responder. (Fig A-1, I-2) The re-entry vehicle responder simulates the function of the pre-launch monitor and the missile re-entry vehicle for the purpose of checking the operation of the re-entry vehicle control logic and launch officers console.

RFB 12.3.3 Engine Responder. (Fig A-1, I-2) The engine responder simulates the function of the missile engine system for the purpose of checking the operation of the engine control logic and launch officers console.

RFB 12.3.4 Countdown Control Responder. (Fig A-1, J-2) The countdown control responder simulates the function of various missile systems for the purpose of checking the operation of the countdown control logic and launch officers console.

RFB 12.3.5 Missile Ground Power Responder. (Fig A-1, J-2) The missile ground power responder simulates the responses of missile power functions for the purpose of checking the operation of the engine control logic and launch officers console.

RFB 12.3.6 Hydraulic and Pressurization Responder

RFB 12.3.6.1 Hydraulic Responder. (Fig A-1, J-2) The hydraulic responder simulates the function of the hydraulic system for the purpose of checking the operation of the hydraulic control logic and launch officers console.

RFB 12.3.6.2 Pressurization Responder. (Fig A-1, K-2) The pressurization responder simulates the function of the pressurization control unit, the helium charge unit, the missile fuel and LO_2 tank pressure differential pressure sensing transducers, and the missile pod air-conditioning blower for the purpose of checking the operation of the pneumatic control logic and the launch officers console.

RFB 12.3.6.3 LN_2/He Tanking Responder. (Fig A-1, K-2) The LN_2/He tanking responder simulates the function of components located in the pneumatic distribution and LN_2 systems for the purpose of checking the operation of the LN_2/He control logic and the launch officers console.

RFB 12.5 Facilities Remote Control Panel. (Fig A-1, I-4) The facilities remote control panel controls, monitors, and gives visual and audible alarms for various facility items such as fans, generators, fire and gas detection systems, sump pumps, utility water pressure, doorways, closures, etc.

RFB 12.5.1 Facilities Interface Cabinet. (Fig A-1, H-5) The facility interface cabinet is used as a bus tie point for signals from launch control and facility items.

RFB 12.5.2 Fuel Prefab Electrical Control. (Fig A-1, H-5) This function contains necessary microswitches, solenoids (electrical part), pressure switches, junction box, and associated wiring to include the cabling from the prefab to RFB 12.5.1, facilities interface cabinet. Its purpose is to provide the control signals to the valves and switches in the fuel loading prefab, and transmit responses back to launch control.

RFB 12.5.3 LO_2 Fill Prefab Electrical Control. (Fig A-1, H-5) This function provides signals for the operation of the fill valves, solenoids, and pressure switches, and returns responses to the launch control. It contains the solenoids (electrical part), microswitches, junction box, and associated wiring to include the cabling from it to RFB 12.5.1, facilities interface cabinet.

RFB 12.5.4 LO_2 Control Prefab Electrical Control. (Fig A-1, H-5) This function contains solenoids (electrical part), pressure switches, junction box, and associated wiring and the cabling from it to RFB 12.5.1, facilities interface cabinet. Its purpose is to provide the necessary signals to operate the above mentioned equipment and to send back to launch control the proper responses.

RFB 12.5.5 Pressurization Prefab Electrical Control. (Fig A-1, H-5) This function provides signals for operating the various pressurization valves, solenoids (electrical part), and pressure switches, and transmits indicator signals back to launch control. It contains five valve controls, two liquid level indicator switches, two pressure switches, associated wiring, and the cabling to RFB 12.5.1, facility interface cabinet.

RFB 12.5.6 PDU Electrical Control. (Fig A-1, H-5) This function contains a series of solenoids (electrical part), several pressure switches, associated wiring. It provides the necessary signals to these relays and switches combined with sending responses back to launch control.

RFB 12.5.7 PCU Electrical Control. (Fig A-1, H-5) This function provides the electrical impulses for the various solenoids and regulators which in turn operate the valves of the PCU and subsequently send indicator signals back to launch control. It consists of numerous solenoids (electrial part), associated wiring, and the cabling to RFB 12.5.1.

RFB 12.5.8 Instrument Air Prefab Electrical Control. This function consists of pressure switches, solenoids (electrical part), air compressor motors, selector switches, associated wiring for elapsed time meters, and an air dryer, and the cabling from it to RFB 12.5.1. Its purpose is to supply the signals to these units and transmit proper responses back to launch control.

RFB 12.5.9 HCU Electrical Control. (Fig A-1, H-5) This function provides response signals back to launch control from the actuation of the pressure switches and valves contained within it. It also includes the associated wiring and the cabling back to RFB 12.5.1.

RFB 12.5.10 TCU Electrical Control. (Fig A-1, H-5) This function consists of various valves, solenoids (electrical part), and associated wiring. Its function is to provide the signals to the valves, etc., and to return responses to launch control.

RFB 12.5.11 LN_2 Prefab Electrical Control. (Fig A-1, H-5) This function is composed of four solenoid switches (electrical part), associated wiring, and the cabling from it to RFB 12.5.1. It provides the signals for the operation of the related valves and sends indicator impulses back to launch control.

RFB 12.5.12 HPU Electrical Control. (Fig A-1, H-5) This function consists of several relays, contacts, indicator lights, switches, motor driven valves, pump motors, transformers, a circuit breaker, and associated wiring to the parts. It must provide the various control signals and 3 phase power required to operate the above parts and also send response signals back to launch control.

RFB 12.6 AMF—MLS Logic System. (Fig A-1, H-5)

RFB 12.6.1 AMF—MLS Logic Units. This function includes the cabinets and chassis with all of their internal circuitry necessary to sequence and test the missile lifting system. The AMF—MLS logic units automatically sequence control of the MLS system during a weapon system mission and performs testing on the MLS system.

RFB 12.6.2 Level 1 MLS Electrical Control

RFB 12.6.2.1 Level 1 J-Boxes and Cabling. This function contains all the J-Boxes on level 1 and the J-Box connecting and the system to the L/P on level 4, the cabling to all other J-Boxes, the AMF—MLS logic unit, the facilities interface cabinet, the hydraulic local control panel, the operating level control station, the L/P guide rail limit switches on level 1, and the motor coupling switches. This function receives and sends control and indicating signals to and from other connected equipments.

RFB 12.6.2.2 Hydraulic Local Control Panel. This function includes the necessary electrical circuitry for receiving or sending control or indicating signals either in local or automatic operation from the hydraulic and nitrogen MLS subsystems solenoids and switches.

RFB 12.6.2.3 Operating Level Control Station. This function includes the panel and the necessary control circuitry to enable the local operation of raising or lowering the launch platform. This function contains control buttons for starting and stopping the 40-hp hydraulic pump, the silo doors and the vertical and horizontal crib locking control buttons and pushbuttons to control the movement of the launch platform.

RFB 12.6.2.4 Motor Coupling Switches. This function includes the switches located on the motor coupling device to indicate its status to the AMF—MLS logic unit.

RFB 12.6.2.5 L/P Guide Rail Switches. This function includes two 1000-inch limit switches located on or near level 1.

RFB 12.6.2.6 Overspeed J-Box and Cabling. This function includes the J-Box and the cabling connecting it to the overspeed device and the L/P guide rail switches located in its vicinity.

RFB 12.6.2.7 Overspeed Sensor. This function includes the overspeed sensor unit and brake electrical mechanism which senses drive motor speed and applies electrical control signals to the brake mechanism.

RFB 12.6.2.8 L/P Guide Rail Switches. This function is defined as the L/P guide rail switches which connect to the overspeed J-Box.

RFB 12.6.3 Mezzanine MLS Electrical Control

RFB 12.6.3.1 Mezzanine J-Boxes and Cabling. This function includes the J-Boxes on the level above level 1 and the cabling connecting the J-Boxes to the various switches in the mezzanine area.

RFB 12.6.3.2 Horizontal Crib-Lock Switches. This function is defined as the horizontal crib-lock switches which indicate the lock status to the logic circuitry and to the operating level control station.

RFB 12.6.3.3 Lower and Upper Door Actuator Switches. This function is defined as the limit switches which indicate the position of the doors to the logic circuitry.

RFB 12.6.3.4 L/P Guide Rail Switches. This function is defined as the L/P guide rail switches which connect to the mezzanine J-Boxes and monitor launch platform ascent and descent.

RFB 12.6.4 Level 2 MLS Electrical Control

RFB 12.6.4.1 Level 2 J-Boxes and Cabling. This function includes all J-Boxes on level 2 and the cabling connecting them to the various valve solenoids and switches for the purpose of control and monitoring.

RFB 12.6.4.2 Work Platform Switches. This function is defined as the limit switches which indicate the work platform position to the AMF—MLS logic circuitry.

RFB 12.6.4.3 Charge and Vent Valve Solenoid. This function is defined as the valve solenoids of the hydraulic and nitrogen subsystem in the MLS system which control the operation of these subsystems.

RFB 12.6.4.4 Charge and Vent Valve Switches. This function is defined as the switches which monitor the status of the charge and vent valve solenoids in the hydraulic and nitrogen subsystems.

RFB 12.6.4.5 Key Switch. This function is described as the key switch assembly located near the work platform on the second level. It purpose is to control locally the extension and retraction of the hydraulically operated work platforms.

RFB 12.6.5 Level 4 MLS Electrical Contract

RFB 12.6.5.1 Level 4 J-Boxes and Cabling. This function includes all J-Boxes on level 4 and the cabling connecting the J-Boxes to the various locking switches for the purpose of control and monitoring.

RFB 12.6.5.2 Vertical Crib-Lock Switches. This function is defined as the vertical crib-lock switches which indicate the position of the vertical locks to the logic circuitry and the control station operating level.

RFB 12.6.6 Level 5 MLS Electrical Control

RFB 12.6.6.1 Level 5 J-Boxes and Cabling. This function includes all J-Boxes on level 5 and the cabling connecting the J-Boxes to the various switches for control and monitoring.

RFB 12.6.6.2 AIG Pod Handling Fixture Switches. This function is defined as the switches which indicate the status of the AIG Pod handling fixture.

RFB 12.6.6.3 Key Switch. This function is described as the key switch assembly located near the work platform on the fifth level. Its purpose is to control locally the extention and retraction of the hydraulically operated work platforms.

RFB 12.6.6.4 Work Platform Switches. This function is defined as the limit switches which indicate the work platform position to the AMF—MLS logic circuitry.

RFB 12.6.7 Level 6 MLS Electrical Control

RFB 12.6.7.1 Level 6 J-Boxes and Cabling. This function includes all J-Boxes on level 6, and the cabling connecting the J-Boxes to the various switches for control and monitoring.

RFB 12.6.7.2 Key Switch. This function is described as the key switch assembly located near the work platform on level 6. Its purpose is to control locally the extention and retraction of the hydraulically operated work platform.

RFB 12.6.7.3 Work Platform Switches. This function is defined as the limit switches which indicate the work platform position to the AMF—MLS logic circuitry.

RFB 12.6.7.4 L/P Guide Rail Switches. This function is defined as the L/P guide rail switches which connect to level 6 J-Boxes for the purpose of monitoring launch platform ascent and descent.

RFB 12.6.8 L/P Electrical Control

RFB 12.6.8.1 L/P J-Boxes and Cabling. This function includes all the J-Boxes on the L/P and the cabling connecting the J-Boxes to the various switches and solenoids for control and monitorning.

RFB 12.6.8.2 L/P Locking Switches. This function is defined as the switches which indicate the locking of the L/P to the silo cap when the L/P is fully up, and to the crib when the L/P is fully down.

RFB 12.6.8.3 L/P Manifold Valve Solenoids. This function is defined as the mainfold valve solenoids which control the wedge and main locks.

SYSTEM 20. 0——INERTIAL GUIDANCE

The all-inertial Guidance system, in conjunction with the autopilot system, provides control of missile flight path and thrust. The AIG function is to properly select engine cut-off points, initiate yaw and pitch steering commands, and coordinate roll maneuvers with the flight programmer of the autopilot system. All AIG functions are channeled through the autopilot system. The AIG system consists of a computer, control center, and an inertial sensing platform.

20. 1 Computer. (Figure A-2, W-3)4 The computer accepts accelerometer data from the control center and generates yaw correction signals and the following discrete signals:

a) Staging Command (BECO)

b) Sustainer Cut-Off (SECO)

c) Vernier Cut-Off (VECO)

d) Warhead Prearm

e) Nosecone Umbilical Ejection

f) Nosecone Separation

g) Fire Retro-Rockets

20. 2 Control. (Figure A-2, W-4) The control center electrically supports the computer and the platform. Accelerometer data is received from the platform, channeled through signal amplifiers, and relayed to the computer. In addition, the control center supplies torquer current to the platform.

20. 3 Platform. (Figure A-2, W-51) The inertial sensing platform is a reference table stabilized by two gyros. Mounted on the platform are three accelerometers that supply data through the control center to the computer. The platform also originates pitch steering commands and roll maneuver signals to the autopilot system.

SYSTEM 21.0— AUTOPILOT SYSTEM

RFB 21.0 Airborne Autopilot System. The autopilot system steers and stabilizes the missile during the powered portion of flight, and provides numerous preset switching functions. The autopilot system consists of the programer, gyro group, servoamplifier and filter, remote rate gyro group, and excitation transformer.

RFB 21.1 Programer. (Figure A-2, V-3) The programer function is defined as the electronic programer cannister component and its connectors. The programmer generates the pitch program and controls the roll program. It provides four timed switching functions, digital time base, staging and backup signals, and provides the safe/arm switching function.

RFB 21.2 Gyroscope Group. (Figure A-2, V-4) The gyro group function is defined as the gyro group cannister including its connectors. The gyroscope group contains pitch, yaw, and roll displacement gyros, and the roll rate gyro. These gyros operate in conjunction with the pitch and yaw rate gyros in the rate gyro group. Together, the gyros and rate gyros maintain the stability of the missile, and change the missile flight path upon receiving steering commands from the programmer or all intertial guidance system.

RFB 21.3 Servoamplifier and Filter. (Figure A-2, V-5) The servoamplifier and filter function is defined as the servoamplifier-filter cannister, including its connectors. The primary function of the servoamplifier filter is to integrate and filter three signals coming from the gyro group, summing signals from the feedback transducers and programed vernier bias, and controlling direct current in each of the hydraulic controllers according to the summed signals.

RFB 21.4 Two-Rate Gyro Group. (Figure A-2, V-4) The rate gyro function is defined as the rate gyro group cannister including its connectors. The rate gyros work in conjunction with the displacement gyros in the gyro group cannister. The pitch, yaw, and roll rate gyros produce an output which is a function of the rate of change of axis displacement, or axis velocity.

RFB 21.5 Excitation Transformer. (Figure A-2, S-6) The excitation transformer function is defined as the excitation transformer cannister including its connectors. It serves two purposes; (1) it provides a 400-cps reference voltage for excitation of the feedback transducers, and (2) provides voltage for vernier bias signals required after staging.

RFB 21.6 Autopilot Cabling. The autopilot cabling function is defined as the harness assembly which interconnects each cannister of the autopilot system and which connects the autopilot to other missile systems. This includes the connectors on both ends of the cables.

SYSTEM 22.0—RE-ENTRY VEHICLE

RFB 22.1 Separation Subsystem. (Figure A-2, X-3) Provides the re-entry vehicle with a separation subsystem which includes a separation mechanism, two explosive squibs, and two load-limiting resistors. Electrical power for separation is provided by the missile electrical system.

RFB 22.2 Arming and Fuzing Subsystem. (Figure A-2, X-4) Provides arming and fuzing control of the warhead. The subsystem consists of two post-separation and two AFS batteries with detonators, and two complete identical arming and fusing systems each with airburst and ground burst options.

RFB 22.3 Structure and Cabling. (Figure A-2, X-4) Provides for re-entry vehicle structure. Separation and arming and fuzing subsystem electrical cabling is also included.

SYSTEM 23.0—PROPULSION

Associated Equipment RFB's (not shown on the diagrams) were generated for the purpose of absorbing those failures of system 23 which occur in linkage and minor support equipments that do not warrant individual RFB distinction.

RFB 23.1 Booster No. 1. (same as Booster No. 2 (23.2) - Figure A-2 (F-J)-(2-7) Booster No. 1 is a bi-propellant liquid, 165,000 pounds fixed thrust, gimballed engine consisting of a tubular wall, fuel regeneratively cooled, hypergol ignited thrust chamber supplied with missile tank stored propellants by a hot gas generator-driven turbopump.

RFB 23.2 Booster No. 2. The system and operating of Booster No. 2 are identical to that of Booster No. 1 except for the exclusion of the hydraulic pump and the inclusion of a helium heat exchanger in the exhaust duct of the turbopump turbine.

RFB 23.2.1 Solid Propellant Gas Generator. (Figure A-2, J-6) The short duration solid propellant gas generator is used to start the booster engines. SPGG Heater (not shown on the functional block diagram) maintains the grain temperature at a suitable level. The SPGG thermostat senses grain temperature and sends a signal to the launch control equipment. Redundancy is supplied by use of two initiators, either of which will ignite the solid propellant. The SPGG burns for approximately 1.3 seconds supplying hot gas to start the turbopump.

RFB 23.2.2 Gas Generator (Figure A-2, J-5) The gas generator supplies the motive power to the turbopump turbine. Subassemblies of the gas generator are two igniters, valve activator, fuel valves and LO_2 valve. Either of the igniters will fire the propellants in the combustor. The valve activator causes the fuel and LO_2 valves to open allowing fuel and liquid oxygen to flow into the gas generator combustor where it is ignited.

RFB 23.2.3 Turbopump. (Figure A-2, I-5) The turbopump operates on hot gas supplied by the liquid-propellant gas generator to provide propellants for the gas generator and thrust chamber, lube oil for the gear case, and through the accessory drive operates a hydraulic pump. The hot gas is exhausted overboard after passing through the turbine. During fuel loading the fuel pump and ducting are filled under missile-fuel-tank pressure. Air trapped in the fuel volute is bled off by the fuel volute bleed valve. During liquid oxygen loading, the liquid oxygen pump and ducting are filled under missile liquid-oxygen tank pressure. During helium loading, the purging of the liquid oxygen pump seal is started.

RFB 23.2.4 Main LO_2 and Fuel Valve Assembly. (Figure A-2, H-6) The RFB is shown on block diagram as RFB's 23.2.4.1 and 23.2.4.2 The main LO_2 and fuel valve assembly control the flow of LO_2 and fuel to the gas generator and thrust chamber. Specifically the turbopump start increases fuel pressure which actuates the directional control valve to open the main LO_2 valve, allowing liquid oxygen to flow to the gas generator and thrust chamber. The main LO_2 valve is mechanically linked to the igniter fuel valve, so the latter also opens to allow fuel to flow to the igniter. The directional control valve receives an electrical signal from the engine relay box which activates it to close both valves. Opening the igniter fuel valve permits fuel pressure to burst the hypergol Cartridge. The igniter fuel flow carrying a portion of the hypergolic fluid into the main fuel valve actuator causes the main valve to open, so fuel flows to the gas chamber and thrust chamber.

RFB 23.2.5 Heaters. (not shown on functional block diagram) Electrical heaters on the gear case, accessory drive, main LO_2 valve, and igniter fuel valve maintain suitable operating temperature.

RFB 23.2.6 Support Equipment. (Figure A-2; H-6, G-6, F-5, H-5) The RFB is shown on block diagram as RFB's 23.2.6.1 through 23.2.6.6 This function contains the Fuel Manifold, Lubricant Tank and Pressurizing Valve, Hypergol Igniter, Thrust Chamber Assembly and Gimbal Bearing, Heat Exchanger for No. 2 Booster only, and Electrical Cable. The manifold distributes fuel to the actuators on those valves actuated

by fuel pressure and to the igniter fuel valve. Lube oil is contained in the lubricant tank. The opening of the lube-tank-pressurizing-valve allows helium to pressurize the lube tank thus forcing the lube oil out to the lube pump. Hypergol igniter contains hypergolic fluid which ignites the fuel and LO_2 in the thrust chamber and establishes an ignition flame. Propellants and hypergol are sequenced to arrive and ignite in the combustion zone of the thrust chamber. The thrust chamber is hydraulically actuated to rotate on the gimbal bearing to obtain variation in thrust chamber position during flight. The heat exchanger, operating on the hot gases from the turbine exhaust, supplies helium to the pneumatic system. This RFB is shown on the block diagram as RFB's 23.2.6.1 through 23.2.6.5.

RFB 23.2.7 Plumbing and Valves. (Figure A-2; J-7) This function provides RPI and LO_2 to the Rocketdyne engines through various propellant fluid transfer valves and associated piping. This is attached in the booster subsystem by use of a propellant tank fill and drain system with piping and valves which lead and attach to the NAA turbopumps which deliver propellant to the booster engine. This RFB is shown on block diagrams as RFB's 23.2.7.1 and 23.2.7.2.

RFB 23.3 Sustainer. The sustainer engine is a bi-propellant liquid, 57,000 pounds fixed thrust, plus or minus 15 percent mixture ratio control, gimballed engine consisting of a tubular wall, fuel regeneratively cooled, hypergol ignited thrust chamber supplied with missile tank stored propellants by a hot gas generator-driven turbopump. The sustainer engine is ground started 350 milliseconds after the booster engines.

RFB 23.3.1 Solid Propellant Gas Generator. (Figure A-2, P-3) The short duration solid propellant gas generator is used to start the sustainer engines. The SPGG Heaters (not shown on functional block diagram) maintain the grain temperatures at a suitable level. The initiators are fired 350 milliseconds after the booster engines. Redundancy is supplied by the use of two initiators, either of which will ignite the solid propellant. The SPGG burns for approximately 1.3 seconds, supplying hot gas to start the turbopump.

RFB 23.3.2 Gas Generator. (Figure A-2, P-4) The gas generator supplies the motive power to the turbine of the turbopump. Redundancy is supplied by the use of two igniters, either of which will ignite the propellants and the combustor. The blade valve actuator is hydraulically activated by the hydraulic control manifold, causing it to open the fuel and LO_2 blade valves. Fuel and LO_2 then flow into the gas generator combustor and are ignited to produce the hot gases for driving the turbopump.

RFB 23.3.3 Turbopump. (Figure A-2, O-3) The turbopump operates on hot gas supplied by the liquid-propellant gas generator to provide propellants for the gas generator and thrust chamber, lube oil for the gear case, and through the accessory drive operates a hydraulic pump. The hot gas is exhausted overboard after passing through the turbine. During fuel loading the fuel pump and ducting are filled under missile-fuel-tank pressure. Air trapped in the fuel volute is bled off by the fuel volute bleed valve. During liquid oxygen loading, the liquid oxygen pump and ducting are filled under missile liquid-oxygen tank pressure. During helium loading, the purging of the liquid oxygen pump seal is started.

RFB 23.3.4 Main Propellant Valves. (Figure A-2; O-3, N-3) This RFB is shown on block diagram as RFB's 23.3.4.1 through 23.3.4.3. This function contains the head suppression, igniter fuel and propellant utilization valves. An electrical signal to the hydraulic control manifold solenoid switches hydraulic pressure to the open port of the actuator, opening the head suppression valve. The head-suppression-valve position is varied during flight by the hydraulic control manifold. During LO_2 loading, the duct to the closed Head Suppression Valves is filled with LO_2. The Igniter Fuel Valve is mechanically linked to the Head Suppression Valve and opens when the latter opens. During fuel loading, fuel fills the lines to the closed Igniter Fuel Valve. The Propellant Utilization Valve is opened by hydraulic actuation from the Hydraulic Control Manifold allowing fuel to flow to the Thrust Chamber. The P.U. Valve RFB contains a feedback transducer which is mechanically linked to the P.U. Valve Gate. Movement of the valve generates a feedback signal which is sent to the Valve Controller Assembly.

RFB 23.3.5 Heaters (not shown on functional block diagram) Heaters are used to maintain suitable operating temperatures for the Turbopump, Head Suppression Valve, and Igniter Fuel Valves.

RFB 23.3.6 Support Equipment (Figure A-2;(N-P)-(2-3) This RFB is shown on functional block diagram as RFB's 23.3.6.1 through 23.3.6.6. Contained within this function are the LO_2 regulator, hydraulic control manifold, hypergol igniter, thrust chamber assembly, lubricating tank pressurization valve and electrical cable. During LO_2 loading, LO_2 flows through the LO_2 regulator. During flight, LO_2 (at high pressure from the turbopump) is reduced to approximately 850 psi by the oxidizer regulator and distributed to the gas generator and vernier oxidizer manifold. The hydraulic control manifold distributes hydraulic pressure to the gas generator blade valve, head suppression valve, and propellant utilization valve. Hypergol igniter contains hypergolic fluid which ignites the propellant in the thrust chamber. Propellants and hypergol are sequenced to arrive and ignite in the combustion zone of the thrust chamber. The thrust chamber is hydraulically actuated to rotate on gimball bearings to obtain variation in thrust chamber position during flight. Lubricating oil is contained in the lubrication tank. The opening of the lube-tank-pressurizing-valve allows helium to pressurize the lube tank, thus forcing lube oil out of the lube pump. Electrical cable supplies 120 v-ac, 3-phase electrical power to the sustainer engine heaters on the SPGG, turbopump, head suppression valve, and igniter fuel valve.

RFB 23.3.7 Plumbing and Valves (Figure A-2, P-3) This function supplies fluid to the sustainer engine through the main fluid transfer valves and piping to the NAA sustainer turbopump. Propellant fluids from the NAA vernier engine propellant valves and onto the vernier engines. After sustainer engine cutoff, propellant fluids from the NAA vernier flow tanks pass through piping to the NAA vernier engine propellant valves and onto the vernier engines. This RFB is shown on the block diagrams as RFB's 23.3.7.1 and 23.3.7.2.

RFB 23.4 Vernier No. 1 (Figure A-2, O-5) Vernier engine No. 1 is a bi-propellant liquid, 1000 pound thrust, gimballed engine consisting of a

small double wall, hypergol ignited, thrust chamber to which propellants are supplied from the sustainer turbopump and pressurized solo tanks through pneumatically controlled linked propellant valves.

RFB 23.5 Vernier No. 2 (Figure A-2, O-5) The system and operating of vernier No. 2 are identical to that of vernier No. 1.

RFB 23.5.1 Propellant Valve (Figure A-2, O-5) This function controls the flow of fuel and LO_2 to the thrust chamber. During fuel and LO_2 loading, the fuel and LO_2 lines of the valve is filled with propellant at missile-fuel-LO_2-tank pressure. To maintain a liquid head of LO_2 at the propellant valve, the vent valve vents excess pressure from the LO_2 section while the propellant valve is closed.

RFB 23.5.2 Support Equipments (Figure A-2, O-6) The function contains the gimbal assembly, hypergol igniter, and thrust chamber. The Gimbal components provide for the thrust vector control about the yaw, pitch, and roll axes of the missile, and are hydraulically controlled from the hydraulic actuators. Propellants in the thrust chamber are ignited after the hypergol igniter diaphragm is burst. Ignition and combustion occur in the thrust chamber to develop the thrust for which the engine is designed.

RFB 23.6 Loose Equipment. This function contains the Pneumatic Control Manifold, Rocket Engine Relay Box, and Support Equipments.

RFB 23.6.1 Pneumatic Control Manifold (Figure A-2, P-5) During countdown, helium is supplied by the pressure regulator to the CLOSE part of the vernier engine propellant valve and is controlled by the propellant valve solenoid. At booster cutoff the solo tanks pressure solenoid controls the flow of helium to the solo tanks, and maintains tank pressure during vernier engine solo tank operation. During booster engine operation, helium is supplied to purge the booster engine turbopump LO_2 seals. The electrical heater (not shown on functional block diagram) maintains a suitable operating temperature.

RFB 23.6.2 Rocket Engine Relay Box (Figure A-2, R-4) The relays control engine operation during flight. The sustainer locking relay is energized from the launch control equipment. The vernier timer delays the energizing of the vernier locking relays for 2 seconds after the sustainer locking relay is energized. The solo tank pressurizing relay prevents a signal from pressurizing the vernier solo tanks until after the booster cutoff relays are energized at the proper times by signals from the missile control system.

RFB 23.6.3 Support Equipments. (Figures A-2, P-5, P-6) These RFB's are shown on functional block diagram as RFB's 23.6.3.1 and 23.6.3.2. This function contains LO_2 and fuel solo tanks. Filling of the LO_2 solo tank is started during liquid oxygen loading and gaseous oxygen is vented through the vent valve. Completion of tank filling occurs prior to booster engine cutoff with LO_2 supplied through a line from the sustainer turbopump. At booster engine cutoff, the vent valve is closed and the tank is pressurized. After sustainer cutoff, the tank supplies LO_2 for vernier engine operation when the tank pressure exceeds the pump pressure.

During the fuel loading, the fuel solo tank is partially filled with fuel. Completion of the tank filling occurs prior to booster engine cutoff with fuel supplied through a line from the sustainer turbopump. The tank is pressurized at booster engine cutoff. After sustainer cutoff, the tank supplies fuel for vernier engine operation when the tank pressure exceeds the pump pressure.

SYSTEM 24.0——SEPARATION SYSTEMS

RFB 24.1 Booster Separation System. (Figure A-2, 6-5) This system jettisons the booster section.

RFB 24.1.1 Valve Installation. The valve installation consists of a cable assembly and 2, two-way, normally closed valves mounted on a fitting to make parallel systems. At staging, the autopilot programmer initiates a signal to the two-way valves and fires a pyrotechnic charge which forces a piston to punch out a metal diaphragm separating the inlet and outlet ports. When the diaphragm is fractured, compressed helium gas from the sustainer ambient helium storage bottle is released into the helium distribution manifold and thence to the four separation fittings, causing them to unlatch.

RFB 24.1.2 Helium Distribution Manifold. This manifold is composed of a number of tube assemblies and distributes helium to the four separation fittings.

RFB 24.1.3 Separation Fittings. There are four separation fittings equally spaced on the periphery of the booster section and adjacent to the line of separation. Each fitting consists of a release assembly, an arm assembly and a bolt assembly. The release assembly contains a spring-loaded piston mounted in a body. The arm assembly mounts the release hook, and the bolt assembly is a special bolt used for adjustment only. When the valve installation is operated, helium gas at 2000 to 3000 psig reaches the piston in the release assembly and allows the release hook to unlatch thus causing mechanical separation between the booster and sustainer sections.

RFB 24.1.4 Jettison Tracks. There are two jettison tracks mounted on the missile tank structure. Fitted to the aft conical bulkhead in Quadrants II and IV, the tracks are supported by two triangular support assemblies mounted on the thrust cone. These jettison tracks are the guides for the slide installations and ensure a straight, smooth separation of the booster section from the sustainer.

RFB 24.1.5 Slide Installations. The slide installations are mounted within the booster section at Quadrants II and IV, and are fitted to the booster structure. Two slides are provided for each jettison track, one fore and one aft.

RFB 24.2 Re-Entry Vehicle Separation System (GD/A). (Figure A-21 X-2) The re-entry vehicle contains its own separation device, and separation does not occur between re-entry vehicle adapter and the re-entry vehicle proper. However, when separation does occur, it is essential that the re-entry vehicle is not distrubed from its programed course. Two retarding rockets, fitted to the missile sustainer section and located in the forward fairing of pod B2, are timed to fire shortly after re-entry vehicle separation. This slows and deflects the missile and ensures "clean" separation.

RFB 24.2.1 Retarding Rocket and Support Installation. This function consists of support for the retarding rockets.

RFB 24.2.2 Rockets. The function of the rockets is to reduce the speed of the missile and deflect the missile trajectory.

SYSTEM 25.0—MISSILE ELECTRICAL SYSTEM

RFB 25.1 Missile 28 vdc Supply. (Figures A-2, S-6) This function is defined as 28 vdc battery and the interconnecting cables and plugs which connect it to the power changeover switch. The missile battery provides all the necessary 28-vdc power to missile-borne components during flight.

RFB 25.1.2 Battery Heater. (Figures A-2, S-7) This function is defined as the battery heater unit and its associated circuitry, including the cables connecting the heater and the umbilicals. The heater provides heat to the battery so that it can be activated prior to flight.

RFB 25.2 Missile 400 cps Inverter. (Figures A-2, T-7) This function is defined as the 400-cps inverter and its associated circuitry, including the cable connecting it to the power changeover switch. The inverter provides all 400-cps power necessary to missile-borne components during flight.

RFB 25.3 Missile Changeover Switch. (Figures A-2, T-6) This function is defined as the changeover switch and its associated circuitry, and the cabling connecting it to the umbilicals. The changeover switch provides all necessary ac and dc power throughout the missile by switching from either external ground power or internal missile power.

RFB 25.4 Missile Power Cabling. (Figures A-2, T-7) This function is defined as the cable harness which distributes all ac and dc power from the changeover switch to missileborne components during flight and countdown missions.

SYSTEM 26.0—MISSILE PNEUMATICS AND HYDRAULICS

RFB 26.1 Missile Hydraulic System

RFB 26.1.1 Booster Hydraulic System

RFB 26.1.1.1 Rise-Off Disconnects. (Figures A-2, D-3) There are two rise-off disconnects for the booster hydraulic system, one for pressure supply from, and one for return to the AGE hydraulic pumping unit. Both these units are located in the lower (Quadrants I and II) disconnect panel and are spring-loaded closed so that on rise-off the system will be sealed.

RFB 26.1.1.2 Hydraulic Fluid Tank. (Figures A-2, J-4) This tank is a pneumatically pressurized fluid reservoir used to supply hydraulic fluid to the booster hydraulic pump. The tank consists of a light alloy cylinder fitted with a free piston which transmits pneumatic pressure to the hydraulic oil. At one end, a machined casting receives hydraulic lines, including supply and return lines and a bleed line. At the other end small fittings receive pneumatic pressurization lines from the ground pressurization fitting and from the missile helium pressure system. A pneumatic relief valve is also fitted in the pneumatic line. This tank is pressurized during standby to 60 psig, and is mounted in Quadrant IV at Station 1157 within the booster airframe.

RFB 26.1.1.3 Hydraulic Pump. (Figures A-2, K-4) The booster hydraulic pump is a variable-delivery type pump providing 3000 psig pressure at about 20 gpm to the booster hydraulic system and provides hydraulic power to the four booster actuators. The pump is driven by booster engine No. 1 and is mounted on the turbopump gearcase, the drive being taken by a splined shaft on the pump. Hydraulic oil supply for this pump is provided directly by a pressurized feed, at 60 psig, from the hydraulic fluid tank. Pressure supply from the pump is taken to the actuators through check valves and distribution manifolds.

RFB 26.1.1.4 Main Manifold. (Figures A-2, K-4) This is the main distribution manifold for separating the hydraulic fluid supply to each set of actuators. The manifold, consisting of a machined block of light alloy,

mounts two check valves and is located between Quadrants III and IV at Station 1177.

RFB 26.1.1.5 Accumulator. (Figures A-2, G-7) There are two accumulators under this RFB; both perform identical functions and are identical units. These accumulators act as buffers for the hydraulic system and as pressure supply units in case of pump failure. They are pressurized from a charge panel at 2600 psig at 70°F. A pressure gauge for each accumulator is provided on the charge panel and is used for monitoring the pressures from outside the missile. The units consist of steel cylinders, domed at one end and fitted with end plugs at the other. The domed ends have the pneumatic fittings for pressurization. The plug ends have fittings for the hydraulic fluid. A free piston transmits the pneumatic pressure to the hydraulic fluid. To prevent ambient temperatures in the booster section from affecting the accumulator pressures, Stafoam insulating jackets are fitted to cover the accumulators, the Stafoam being protected by a steel cover. These accumulators are located at Station 1155, one in Quadrant I, the other in Quadrant II.

RFB 26.1.1.6 Supply Manifold. (Figures A-2, G-6) Two manifolds identical in structure and function are listed under this RFB. Both provide hydraulic fluid supply to the actuators, one dividing the supply to booster engine No. 1 actuators, the other to booster engine No. 2 actuators. Sometimes known as booster Y manifolds, these units are bolted and mounted with their respective return manifolds (RFB 26.1.1.9).

26.1.1.7 Actuator. (Figures A-2, F-6) There are four actuators in the booster hydraulic system, two for each engine. With the exception that two of the actuators operate the thrust chambers in a different plane from the other two, the functions and construction are the same. Each actuator is supplied by hydraulic power through manifolds and piping and is controlled by a servo-valve mounted on the actuator. Signals from actuator-mounted transducers are received by the autopilot system, interpreted, and transmitted back to the servo-valves, which, in conjunction with flight requirements, supply the correct amount of hydraulic power required. The fixed ends of the actuators are attached to the booster airframe with bolts through self-centering bushes in the actuators. The movable ends

(in the piston rods) are fitted to a tripod frame on the thrust chambers. The engines, being mounted on gimbals, are free to move when the actuators operate and thus control the direction of flight of the missile.

RFB 26.1.1.8 Cabling. This function consists of cabling for the booster hydraulic system.

RFB 26.1.1.9 Return Manifold. (Figures A-2, G-6) Also under one RFB, these two manifolds are identical in structure and function, being return manifolds from the actuators. Each manifold receives the return flow from the two actuators of one engine and delivers these flows to the main return line to the hydraulic fluid tank. These manifolds are bolted to their corresponding supply manifolds.

RFB 26.1.1.10 Staging Disconnect (Booster Half). (Figures A-2, L-4) These disconnects, mounted on the booster section, mate with the disconnects on the sustainer section in Quadrant II.

RFB 26.1.1.11 Plumbing Valves and Filters. (Figures A-2, G-4) Under this RFB are all the hard and flexible lines, the check valve, the flow limiter valve, relief valve, and the filters in the actuators.

RFB 26.1.2 Sustainer Hydraulics

RFB 26.1.2.1 Staging Disconnects (Sustainer Half). (Figures A-2, L-4) There are two sustainer hydraulic system staging disconnects mounted on the sustainer staging disconnect panel in Quadrant II. These disconnects are in the supply and return lines of the AGE hydraulic pumping unit and mate with disconnects in the booster section.

RFB 26.1.2.2 Hydraulic Fluid Tank. (Figures A-2, L-4) Being similar to the booster system hydraulic tank, this tank also is a pneumatically pressurized fluid reservoir pressurized to 60 psig. The pump takes the hydraulic fluid supply from this tank and delivers hydraulic power to both the sustainer and the vernier systems. A machined casting at one end of the tank is fitted with hydraulic connections for the supply and return lines, and a bleed line. At the other end a pneumatic pressurization line is fitted which enables the tank to be pressurized by ground equipment and by the

missile pneumatic system. A relief valve is fitted into this line. A free piston transmits the pneumatic pressure to the hydraulic fluid. The tank is mounted on the aft conical bulkhead in Quadrant IV.

RFB 26.1.2.3 Hydraulic Pump. (Figures A-2, O-3) Driven by the sustainer engine and mounted on the turbopump gearcase, the sustainer hydraulic pump supplies hydraulic power to both the sustainer engine actuators and the actuators for the vernier engines. This pump is a variable-delivery type producing 3000 psig at designed operating conditions. The hydraulic fluid tank provides the pump with 60 psig fluid supply. The pump delivers hydraulic power to the sustainer and vernier systems through check valves and filters.

RFB 26.1.2.4 Power Distribution Manifold. (Figures A-2, N-4) The vernier solo power supply panel mounts the vernier solo accumulator, the manual two-way flow uniting valve, and the power distribution manifold. This manifold receives hydraulic power direct from the sustainer hydraulic pump and distributes it to the sustainer and vernier systems through check valves mounted on this manifold. The sustainer engine control package also receives missile hydraulic power through this manifold.

RFB 26.1.2.5 Accumulator. (Figures A-2, N-4) The sustainer system accumulator is identical to the booster system accumulator and also acts as a buffer and emergency supply to the hydraulic system. The accumulator is pressurized from the charge panel at 2600 psig at 70°F, and a pressure gauge for monitoring this pressure is located on the charge panel. The unit is a steel cylinder, domed at one end and fitted with an end plug at the other. A free piston transmits the pneumatic pressure to the hydraulic fluid. An insulating jacket is fitted to the accumulator to prevent ambient temperatures from affecting the accumulator pressure. This accumulator is located in Quadrant IV on the aft conical bulkhead.

RFB 26.1.2.6 Manifold. [Figures A-2, (M-N)-4] The sustainer hydraulic manifold has two separate systems—supply and return—and is used to handle the hydraulic fluid to and from the sustainer engine actuators. The supply section of this manifold has five connections: 1) supply from the hydraulic pump (sustainer or AGE hydraulic pumping unit) via a non-return

valve, 2) the line from the sustainer hydraulic accumulator, 3) supply to the vernier system (through a non-return valve), and 4) and 5) one supply line for each of the sustainer engine actuators. The return section carries the two hydraulic return lines from the sustainer engine actuators, one return line from the vernier system, and a line to the hydraulic fluid tank. This manifold is mounted on the aft conical bulkhead in Quadrant I.

RFB 26.1.2.7 Sustainer Actuator. (Figures A-2, M-3) There are two actuators in the sustainer engine system under this RFB: one for the pitch axis and one for yaw. The construction and function of these actuators are identical. Each actuator is supplied by hydraulic power through the manifold (RFB 26.2.2.8) and flexible piping and is controlled by a servo-valve mounted on the actuator. The autopilot system sends signals to this servo-valve and controls the flow of hydraulic fluid accordingly. Transducers mounted on the actuators send signals to the autopilot system and assist in interpreting the hydraulic power required by the actuators. The actuators are fitted between the thrust chamber and the thrust cone, the piston rod end of each actuator being attached to a fixed tripod frame on the thrust chamber and the cylinder end to the thrust cone on the airframe. A gimbal installation is fitted to the sustainer engine and the thrust cone, enabling the engine to move in any direction when controlled by the actuators.

RFB 26.1.2.8 Rise-Off Disconnects. (Figures A-2, L-3) The two rise-off disconnects for the sustainer/vernier hydraulic system are fitted into the lower disconnect panel in Quadrants I and IV, which is mounted on the booster section. Hydraulic power to and from the AGE hydraulic pumping unit is brought through these disconnects. The disconnects are valves, kept open by the ground disconnect fittings. At rise-off the airborne disconnects close and seal the airborne sustainer/vernier hydraulic system.

RFB 26.1.2.9 Cabling. All the airborne wiring and cables required for the sustainer/vernier hydraulic system are included in this RFB.

RFB 26.1.2.10 Plumbing, Valves, and Filters. This RFB covers all the hard and flexible lines in the sustainer/vernier hydraulic system; the six check valves; a relief valve to the hydraulic fluid tank; the two-way,

flow-limiting valve; the filters in the actuators; the two filters in the vernier supply line; and the four vernier flow limiters.

RFB 26.1.3 Vernier Hydraulics

RFB 26.1.3.1 Accumulator (Vernier Solo). (Figures A-2, N-5) This unit is mounted on the vernier solo panel in Quadrant IV and is charged with dry nitrogen at 1000 psig. This cylindrical accumulator contains a free piston which conveys the pneumatic pressure to the hydraulic fluid when required.

RFB 26.1.3.2 Vernier Actuator (Pitch). (Figures A-2, N-5) There are two pitch actuators in the missile vernier system, one for each vernier engine. These two actuators perform similar functions and are identical in design and construction. A special, double-ended piston is made with a rack between the piston ends. This rack engages with a pinion on the vernier engine and rotates it in the pitching plane. The piston is mounted in a single steel cylinder casting, with each piston end in a separate cylinder and the casting cut away between the cylinder ends to expose the rack. Transducers mounted on the cylinder castings and connected to the exposed portion of the piston send feedback signals to the autopilot regarding engine position. Hydraulic fluid is supplied to the actuator through a flow limiter valve for each pitch actuator and thence to the servo-valve which, upon receipt of signals from the autopilot system, supplies the required amount of fluid to the desired side of the piston. These actuators are mounted parallel with the vernier engines and on the engine supports.

During the first two phases of the flight, i.e., flight with booster, sustainer flight only up to sustainer engine cut-off, hydraulic power to the vernier engine actuators is supplied by the sustainer-engine-driven pump. Upon sustainer engine cut-off, hydraulic power to the vernier system is supplied by the vernier solo accumulator system.

RFB 26.1.3.3 Vernier Actuator (Roll and Yaw). (Figures A-2, N-6) There are two roll and yaw actuators performing the same function and identical in design and construction. Differing slightly from the pitch actuators (RFB 26.2.2.20), the roll and yaw actuators contain two snubber pistons, one at each end to absorb shocks during vernier engine

movements which reach the limit of their travel. The double-ended piston is made with a rack cut into it between the piston ends, and the cylinder casting is cut away to allow this rack to protrude and engage with a pinion on the engine. Transducers are mounted on the cylinder castings and connect with the exposed part on the piston, sending signals to the autopilot regarding engine position. Hydraulic fluid is supplied to the actuator through a flow limiter to the servo-valve and also directly to each side of the piston through the snubber pistons. The servo-valve receives signals from the autopilot and directs hydraulic flow to one side or the other of the pistons as required.

During the first two phases of the flight, i.e., booster flight and sustainer flight, and up to sustainer engine cut-off, hydraulic power to the vernier engine actuators is supplied by the sustainer-engine-driven pump. Upon sustainer engine cut-off hydraulic power to the vernier system is supplied by the vernier solo accumulator system.

RFB 26.2.1 Booster Pneumatic System

RFB 26.2.1.1 Rise-Off Disconnects. (Figures A-2, D-4) There are six rise-off disconnect fittings for the missile pneumatic system, including the liquid nitrogen supply disconnects. Mounted on the lower rise-off disconnect panel are: the fuel tank pressurization duct disconnect, the ambient helium bottle (sustainer section) charging line disconnect, and the liquid nitrogen disconnect for the lower two shrouded helium storage spheres. On the upper disconnect panel are: disconnects for oxidizer tank pressurization, helium charging for the six shrouded helium spheres, and liquid nitrogen supply for the four upper shrouded spheres.

RFB 26.2.1.2 Helium Storage Spheres (Shrouded). (Figures A-2, J-5) There are six shrouded helium storage spheres in the booster section of the F-series missile. Four of these are mounted in the upper section of the booster (Quadrants III and IV). The other two are in the lower section (Quadrants I and II). Each sphere is an assembly of two spheres, one within the other, mounted concentrically to provide an even space between the spheres. This space is filled with liquid nitrogen during countdown to chill the helium gas in the inner sphere. This helium gas, loaded during

countdown, provides the propellant tanks with pressurization during the first stage of the flight, i.e., up to the booster separation. Special ducting, fitted with expansion bellows, connects the outer spheres and handles the liquid nitrogen which is supplied from the AGE through two lines from the two rise-off disconnects. One line supplies the four spheres in the upper half of the booster. The other line supplies the two spheres in the lower half. The helium is supplied through one rise-off disconnect to all six bottles, the bottle connections being through the mounting fittings. Special frame-type mountings support the helium storage bottles in the booster section.

RFB 26.2.1.3

a) Pressure Regulator (LO_2 Tank Pressurization). (Figure A-2, K-5) This unit consists of two sections, the regulator controller and the regulator. The object of this installation is to regulate the pressure within the oxidizer tank during the first phase of flight, i. e., until booster separation. While liquid oxygen is being consumed the ullage volume increases and the regulator maintains a constant pressure with increased ullage volume. Helium from the shrouded storage bottles enters the regulator via a motor-controlled valve (RFB 26.2.1.4) and a heat exchanger mounted on the turbine exhaust duct of booster engine No. 2. During ground pressurization, helium (or nitrogen) is supplied and controlled direct to the pressure regulator and oxidizer tank. The regulator controller receives sensing line pressure signals, and the regulator controls the helium (or nitrogen) to or from the oxidizer tank.

b) Pressure Regulator and Relief Valve Installation (Fuel Tank). With the exception that this regulator and relief valve are mounted differently from the oxidizer tank regulator and relief valve, the functions are the same.

RFB 26.2.1.4

a) Motor-Controlled Valve (Changeover Valve). (Figure A-2, I-5) To open the shrouded helium storage bottles to the missile pneumatic system, the motor-controlled valve is operated during the commit sequence. Except for countdown and checkout, this valve always remains closed while the missile is on the ground. The valve is operated by a 28-vdc electric motor and is an integral part of it. Power supply is from the AGE only and the valve is opened during countdown. After rise-off, the valve cannot receive power and remains open throughout the flight.

b) Pressure Line (LO_2 Tank Pressurization). This line or duct (2-3/4 inch diameter) is in two parts: 1) a plain duct, terminating at the radiation shield in a rise-off disconnect fitting on the upper rise-off disconnect panel, and 2) a fabricated straight duct with two bellows installations having a branch duct for connecting to the regulator. This straight portion terminates in a separation disconnect fitting mounted on the booster staging disconnect panel in Quadrant IV.

c) Sensing Line (LO_2 Tank Pressurization). A small-diameter line connecting the LO_2 tank pressure regulator to a staging disconnect fitting, this line forms a continuation of the sustainer LO_2 tank sensing line.

d) Pressure Line (Fuel Tank Pressurization). Similar to the LO_2 tank pressurization duct, this line or duct connects a rise-off disconnect fitting on the lower rise-off disconnect panel to a separation disconnect on the separation disconnect panel in Quadrant II. A branch duct connects to the fuel tank pressure regulator.

e) Sensing Line (Fuel Tank Pressurization). Forming a continuation of the sensing line from the sustainer section, this small-diameter line terminates at one end in a separation disconnect fitting and at the other in the fuel tank pressure regulator.

RFB 26.2.1.5 Staging Disconnects. (Figure A-2, K-5) The staging disconnects on the booster section mate with those of the sustainer in Quadrants II and IV and consist of the fuel and oxidizer tank pressurization and sensing line disconnects in Quadrants II and IV, respectively, and the ambient helium storage bottle supply line disconnect and the liquid oxygen tank vent duct disconnect, both in Quadrant IV.

RFB 26.2.1.6 Piping, Lines, Valves and Regulators. This function all piping, lines, valves and regulators not otherwise covered by RFB's.

RFB 26.2.1.7 Liquid Nitrogen Shrouds. (Figure A-2, J-5) These are the outer spheres surrounding the helium spheres proper, forming the space between the two spheres to provide a volume for the liquid nitrogen. These shrouds vent to the liquid nitrogen evaporator through ducts passing through the radiation shield.

RFB 26.2.1.8 Cabling. This function includes all the airborne electrical wiring required for the booster section pneumatic system.

RFB 26.2.2 Sustainer Pneumatic System

RFB 26.2.2.1 Staging Disconnects. (Figure A-3, L-5) The staging disconnect panels are mounted on the booster separation guide rails, one in Quadrant II, the other in Quadrant IV. The pneumatic system staging disconnects are mounted on these panels, the fuel tank pressurization duct disconnect being in Quadrant II, the disconnect for the oxidizer tank pressurization duct being in Quadrant IV. The sensing line disconnects are mounted one each on the two panels, and the ambient helium storage bottle supply disconnect is mounted on Quadrant IV as is the liquid oxygen tank vent duct disconnect. These six disconnects mate with similar disconnects on the booster section.

RFB 26.2.2.2 Ambient Helium Storage Bottle. (Figure A-2, N-5) This storage bottle is a welded steel sphere mounted on the Quadrant II separation guide rail support. A special A-frame supports the bottle at one side, the other side being on the guide rail support. The mountings and the pneumatic connections for the bottle form integral fittings on the bottle. The vernier pneumatic manifold and the booster separation system are supplied with helium pneumatic pressure from this bottle.

RFB 26.2.2.3 Boil-Off Valve. (Figure A-2, L-5) The primary purpose of the boil-off valve is to prevent excessive vapor pressure in the oxidizer tank during liquid oxygen loading. The boil-off valve setting for the "F" missile is from 3.5 to 5.0 psig.

a) Five main components make up one type of boil-off valve; these are: bellows assembly, hub assembly, cone assembly, solenoid valve assembly, and the duct assembly. The bellows assembly is a double, concentric set of stainless steel bellows with a sealed volume between the two. The contraction of the bellows opens the valve, the seal area being between the bellows and the cone assembly. This assembly is mounted on a stainless steel fabricated body. The hub assembly forms a guide for the bellows and acts as a duct for the escape of the liquid oxygen vapor. The cone assembly, mounted concentrically with the bellows, carries the seal which mates with the bellows. Control of the boil-off valve is accomplished by the solenoid-valve assembly. This assembly contains two solenoids, one for actuating the valve and one, a spring-loaded latch solenoid, for locking. To convey the liquid oxygen vapor from the boil-off valve to

atmosphere, a light alloy duct assembly, bolted to the hub assembly, connects with the short duct in the re-entry vehicle adapter. The complete boil-off valve assembly is bolted to the top of the forward bulkhead, interfacing with the stainless steel ring surrounding the oxidizer tank access hole.

b) Oxidizer Tank Pressure Relief Valve. The purpose of the oxidizer tank relief valve is to vent pressures exceeding 28.0 psig during flight only. The valve has connections from the airborne pressurization supply and from the sensing line. Ducts connect this valve to the oxidizer tank for exhaust to atmosphere. Until booster separation, ground and in-flight pressurization is accomplished through this valve.

c) Pressurization Duct (LO_2 Tank). This pressurization duct, (2-3/4 inches in diameter) is fabricated of seam-welded stainless steel. The duct is in two main sections: 1) starting at the relief valve, a contoured pipe mounted on the aft conical bulkhead, and 2) a straight run of eleven sections mounted on the outside of the fuel and oxidizer tanks, running forward to terminate at the manual shut-off valve mounted at the top of the oxidizer tank. The straight portion of the duct assembly is mounted on special brackets welded to the missile skin and held in place by clamps. Bellows-type expansion joints connect each section, the bellows being protected by shields.

d) Sensing Line (LO_2 Tank Pressurization). This is a small-diameter line made up of several tubing assembly sections and carried within the wiring and tubing tunnel on the outside of the tanks. Several expansion loops allow for temperature changes. Starting at the top of the oxidizer tank, the line terminates at the oxidizer tank pressure relief valve and at the sensing staging disconnect. A manual-disconnect fitting is installed in the line for checkout purposes.

e) Pressure Line (Fuel Tank Pressurization). The fuel tank pressurization line or duct consists of two parts. Connected to the relief valve at one end, this contoured, one-piece duct is mounted on the fuel tank aft bulkhead and connects with a straight section. This straight duct terminates at the manual shut-off valve and has two bellows-type expansion joints.

f) Sensing Line (Fuel Tank Pressurization). This small-diameter line connects the sensing line staging disconnect fitting to the fuel tank and is made up of several tube assemblies; it is located on the fuel tank aft bulkhead. A manual disconnect fitting is installed in the line for checkout purposes.

RFB 26.2.2.4 Transducer LO_2 Tank Pressure.

a) This transducer is located on the forward bulkhead and senses liquid oxygen tank pneumatic pressure, transmitting an electrical signal through the logic unit to a gage mounted on the launch officer's control panel where tank pressure is monitored. In addition to monitoring tank pressures this transducer is tied in with some of the logic circuits to operate warning and status lights.

b) Transducer Fuel Tank Pressure. This transducer performs a function similar to transducer LO_2 tank pressure but is located in pod B-1 and senses fuel tank pneumatic pressures.

c) Pressure Differential Switch and Transducer. This installation is mounted within equipment pod B-2 and consists of two units, the switch and the transducer. Both these units are used for ground instrumentation only. The pressure switch will operate an alarm bell and cause the boil-off valve to open when the differential pressure between the oxidizer and fuel tank drops below a specified level. The transducer sends signals to the differential pressure gage on the launch officer's control console to provide a reading of differential pressure.

RFB 26.2.2.5 Piping and Lines. (Figure A-2, L-5)

a) This function includes all flexible and hard lines not otherwise covered by RFB's.

b) Valves, Regulators and Gauges. This block covers four items. These are two sensing line manual disconnects which are used for connecting the MDU (Pneumatic Test Set) to the missile sensing system, using hose 51. The disconnects are mounted on a panel under a hinged cover and are located at the rear of the AIG pod. To monitor, the pneumatic pressures in the hydraulic accumulators, two gauges mounted on a panel behind the AIG pod are provided. A hinged cover protects these gauges.

c) Cabling. This function includes all the airborne electrical wiring required for the sustainer pneumatic system.

SYSTEM 27.0—PROPELLANT UTILIZATION

RFB 27.1 Fuel Sensor. (Figures A-2, S-3) The function of the fuel sensor is to detect the receding level of fuel at the level at which it is stationed. When the medium surrounding the sensor changes from liquid to gas, the sensor undergoes an electrical change which serves as an informative signal to the computer. Mounted beside the primary string sensors on each sensor-stillwell assembly is an alternate string of sensors. This secondary sensor string serves as an auxiliary. Each string terminates at its own tankwall connector located in the tank wall.

RFB 27.2 LO_2 Sensor. (Figures A-2, S-2) The function of the LO_2 sensor is to detect the receding level of LO_2 at the level at which it is stationed. When the medium surrounding the sensor changes from liquid to gas, the sensor undergoes an electrical change which serves as an informative signal to the computer. Mounted beside the primary string sensors on each sensor-stillwell assembly is an alternate string of sensors. This secondary sensor string serves as an auxiliary. Each string terminates at its own tankwall connector located in the tank wall.

RFB 27.3 Computer. (Figures A-2, T-3) Signals from the fuel and LO_2 sensor-stillwell assemblies are transmitted to the computer assembly which measures any time difference between the signals. When the propellant liquids of each tank empty at an optimum rate, signals from each pair of station sensors are received by the computer at the same instant. However, if a time difference exists between the two signals, this "error time" is measured by the computer which converts it to a correction control signal to cause the change of position of the PU valve in the missile propellant flow system. The function of the computer assembly is, therefore, to correct and maintain an optimum mixture ratio between the two propellant liquids, thereby minimizing the amount of propellant residuals left in the tanks at SECO (sustainer-engine-cutoff) time.

SYSTEM 28.0—MISSILE AIRFRAME

RFB 28.1 Booster Section. The missile booster section (airframe) is the structure which carries the two booster engine installations complete and the missile pneumatic system. The structure consists of a lightweight alloy thrust cylinder bounded at the forward end by a thrust ring and at the aft end by the radiation shield. Two nacelles, one on either side, fair in and protect the two booster engines. The thrust cylinder is a cylindrical shell of lightweight alloy reinforced with longitudinal stiffeners and three belt frames. Two thrust longerons are located 180 degrees to each other and take the thrust of the booster engines. There are also two longerons which terminate at the aft end to pick up the rise-off release latches when the missile is in the vertical position. The thrust cylinder also includes the two engine fairings.

a) Thrust Ring. At the forward end of the thrust cylinder, a thrust ring divided into segments is riveted to the cylinder shell. This thrust ring mates with the thrust ring on the sustainer section using guide pins for correct location. The two sections, booster and sustainer, are held together by four separation latches.

b) Structure Shell. This is a lightweight alloy shell having external longitudinal stiffeners, mounting brackets for engine pumps, interframe braces, longerons and cut-outs for the two engines, the four separation latches and other equipment. Four booster separation slides are mounted in the shell and two radiation shields are riveted to the outside of the shell to prevent heat damage from the vernier engines.

c) Radiation Shield. The radiation shield forms the aft boundary of the booster section at station 1269 and is in four panel assemblies. Two of the assemblies are attached to the cylindrical portion of the thrust cylinder and the other two are fitted to the fairings. Each panel assembly includes a semi-flexible insulated steel blanket with openings for disconnects. The radiation shield complete has three large openings for the three engines.

d) Nacelles. The left hand and right hand nacelles are similar and are located at either side of the cylinder. The nacelles are made of aluminum honeycomb cores bonded to laminated fiberglass skins and form fairings for the two booster engines. Access panels are provided, and the forward ends of the nacelles are in the form of hinged doors.

RFB 28.2.1 (Figures A-2, R-4) Forming the aft end of the sustainer section and being a structural continuation of the oxidizer tank, the fuel tank is a thin stainless steel shell fabricated by heliarc welding. The forward end is bound by the intermediate bulkhead which forms the division between the oxidizer and fuel tanks. The aft end is a cone known as the aft bulkhead to which is mounted the thrust cone. This thrust cone mounts the sustainer engine. In order to enter the fuel tank an access hole is provided at the apex of the aft bulkhead. This hole is surrounded by a stainless steel flange on which is mounted the thrust cone. A special fuel tank for the vernier engines is mounted within the missile fuel tank and may be removed through the access opening if required. Continued from the oxidizer tank and mounted on the outside of the fuel tank are the liquid oxygen fill and drain lines and the oxidizer tank pressurization duct.

a) Intermediate Bulkhead. This bulkhead forms the forward end of the fuel tank and the aft end of the oxidizer tank. The structure is made up of thin stainless steel gores and is welded to the fuel tank section. Forming a division between the two tanks and domed into the oxidizer tank, this bulkhead is designed to support the weight of the liquid oxygen when the missile is in the vertical position. Pressure in the fuel tank in excess of the oxidizer tank pressure ensures structural shape and integrity of the intermediate bulkhead. In some missiles, insulating material is sandwiched between the stainless steel bulkhead proper and a light alloy bulkhead located on the fuel tank side.

b) Structure Shell (Fuel Tank). The fuel tank structure shell is similar to the oxidizer tank, being built up of thin stainless steel bands, lap welded together by the heliarc process.

c) Aft Bulkhead. The aft bulkhead also of thin stainless steel, is made up of shaped bands and tapered segments welded together. Longitudinal stiffeners welded to the skin assist structural stability and are used in some cases as mountings for lines.

Welded to the outside and at the forward end of the aft bulkhead is a circumferential thrust ring which forms the mating face for the booster section. This interface is also the line of separation during flight.

Also mounted on the aft bulkhead are the separation fittings, valves, jettison rails, lines and stiffeners.

d) Thrust Ring. To form an interface between the sustainer and booster sections both for assembly and separation, two thrust rings are provided. One of these is on the sustainer airframe located at station 1133. The stainless steel thrust ring is the member which joins the fuel tank cylinder section to the aft bulkhead. The joint is made by welding. The aft cableway fairing is located directly forward of the thrust ring and is protected by cableway fairing.

e) Membrane Bulkhead. The membrane bulkhead is a flat, lightweight alloy diaphragm riveted to a stiff, flanged former. This bulkhead is riveted to the aft bulkhead in the fuel tank at the joint between the cylindrical section and the aft bulkhead. This membraine is used primarily as a structural member to retain the circular section of the tank during a depressurized, streched condition. The diaphragm proper contains holes to permit the passage of the fuel and to act as an anti-vortex device. At the center of the diaphragm (and for entry into the tank) there is a circular access hole secured by screws.

f) Thrust Cone. The thrust cone is designed to transmit the thrust from the sustainer engine to the sustainer section. The cone assembly consists of a membrane, two link assemblies, and the cone proper. The cone proper is a machined lightweight alloy forging, made with a mating flange to interface with the mounting flange which surrounds the access hole on the aft bulkhead, and forged with bosses for the link mountings, pre-valve outlet boss, and other fittings. The membrane, also of light alloy, is machined from the solid and consists of a thin diaphragm, containing lightening holes, strengthened with stiffeners, and with a square hole at the center. This membrane is bolted to the cone. The links are designed to connect the hydraulic actuators to the thrust chamber of the sustainer engine and are made up of two bi-pods and two connecting links, each assembly being bolted to the cone at the forged bosses. A flat pad at the aft end of the cone forms the mount for the sustainer engine gimbal and is the face which receives the total thrust from this engine.

RFB 28. 2. 2 Oxidizer Tank. (Figures A-2, R-5) Forming the forward end of the airframe proper, the oxidizer tank consists of a thin stainless steel shell fabricated by heliarc welding. The forward end is sealed by a domed bulkhead which is known as the forward bulkhead and is also made of thin stainless steel. (The boil-off-valve is mounted in this bulkhead. The aft end is sealed by the intermediate bulkhead and is considered part of the fuel tank. Within the oxidizer tank there is a baffle

assembly designed to prevent excessive movement of the oxidizer during flight. Near the aft end and mounted on the outside of the oxidizer tank tow elbows located 180 degrees to each other connect to the oxidizer fill and drain lines. Also mounted externally is the oxidizer tank pressurization line and the wiring and tubing tunnel. Structural integrity of the oxidizer tank is maintained by pneumatic pressurization.

a) Oxidizer Tank Shell. The shell consists of two shapes: a cylinder and the frustrum of a cone. Each shape is built-up from thin stainless steel bands lap welded together by the heliarc process. Pneumatic pressurization is normally used to maintain the shape of the tank both on the ground and in flight. However, in cases where a depressurized stretched condition is required a special narrow ring-type bulkhead is fitted as part of the permanent structure to maintain, in particular, the circular shape of the tank. This is located at the joint between the cylindrical and conical sections and prevents the tank from collapsing or changing shape during stretch.

b) Baffle Installation. Eleven light alloy circular baffles, having a top hat section, are spaced and mounted together on light alloy tubes. The whole assembly is mounted at the aft end within the tank, by a number of radially located stirups. This assembly forms the baffle installation.

c) Forward Bulkhead. Thr forward bulkhead is constructed of several gores, heliarc welded into a sub-assembly forming a dome-shaped structure. The gores are of thin stainless steel similar to the oxidizer tank shell. A stainless steel circular flange welded to the top of the dome forms an interface mounting for the boil-off valve. This bulkhead is welded to the forward end of the oxidizer tank.

RFB 28.2.3 Equipment Pods. (Figures A-2, V-7) The two missile equipment pods, B1 and B2, are mounted on the outside of the fuel tank, B2 being the left hand pod and B1 the right hand. The B1 pod contains equipment only for R and D missiles. In the case of IOC missiles this pod remains empty. The B2 pod contains all the equipment required for missile guidance and control and includes the large AIG pod.

a) AIG Pod. This is the largest of all the pods, containing the All Inertial Guidance equipment which includes the computer and guidance platform. The pod structure is based on a metal frame, reinforced with heavy plastic divisions and sub-panels. The sides, end plates, and the two access covers are painted, metallized fibreglass honeycomb.

The AIG pod is mounted to the missile by bolts and shear pins and to brackets welded to the fuel tank skin. The access covers are held in place by latches, six for the large cover and four for the small.

b) Equipment Pod B2 (Left Hand). The B2 pod is in three parts; pod nose fairing; pod door; and the transition fairing. All are constructed of fiberglass honeycomb. The pod nose fairing is attached to the missile by screws and is fitted with two light alloy blow-off covers to provide protected exhaust outlets for the retarding rockets. The pod door is mounted on hinges which are welded to the missile skin. The aft or transition fairing, which fairs in the AIG pod is attached by screws.

c) Equipment Pod B1 (Right Hand). Pod B1 is made up of four separate units; pod nose fairing; pod forward fairing; pod door; and pod aft fairing. With the exception of the pod nose fairing which is made of fiberglass laminate, these fairings are made of fiberglass honeycomb. The fairings are attached with screws. The pod door is attached to the missile with four hinges spot welded to the fuel tank.

d) Wiring and Tubing Tunnel. Running forward from the forward end of pod B2 to the re-entry vehicle adapter, the wiring and tubing tunnel forms a protective cover for boil-off valve, rate gyro and re-entry vehicle wiring and the oxidizer tank sensing line. The tunnel is a thin semicircular stainless steel shell. The rate gyro cannister, located about 10-feet forward of pod B2, is faired into the wiring and tubing tunnel with a fiberglass fairing. When required, a cooling duct from the B2 air conditioning supply is installed within the wiring and tubing tunnel to provide the rate gyro with cooling air.

RFB 28. 2. 4 Re-entry Vehicle Adapter. (Figures A-2, X-4) The adapter is a light alloy, monocoque structure, truncated-conical in shape. Bolted to the forward end of the liquid oxygen tank, the adapter mounts the re-entry vehicle and is fitted with a boil-off valve chute, fittings for the stretch struts, a cableway fairing and an access hole for re-entry vehicle and boil-off valve servicing.

a) Re-entry Vehicle Adapter Structure. The adapter structure consists of a light alloy skin attached to circular formers including fore and aft rings. Local zee sections stiffen the structure as required, and doublers surround access openings and fitting attachments. Two self-aligning bearings are mounted in two retainers located

180 degrees to each other and are for receiving the two stretch strut pins. The fore and aft rings form the mating faces for the re-entry vehicle (station 455.00) and the forward end of the oxidizer tank (station 502.00) respectively. A circular fairing mounted on the skin slightly forward of station 502.00 acts as a heat shield for the attachment bolts.

b) Boil-off Valve Chute. This chute is simply a short tube fixed at one end to a doubler plate or "door" and unsupported at the other to mate with the boil-off valve duct. A special seal is provided for this duct connection.

c) Stretch Strut Fittings. There are two of these fittings, fitted into the re-entry vehicle adapted and located 180 degrees to each other on the outside skin. The fittings consist of self-aligning steel sockets and receive pins attached to the ground system stretch mechanisms to take the stretch loads.

d) Cableway Fairing. This fairing is a preformed fibreglass shell connecting and terminating the wiring and tubing tunnel on the missile tanks and fitted in a retainer attached to the adapter skin.

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APPENDIX B
MATHEMATICAL TECHNIQUES

B.1 SERIES RELATIONSHIP (PRODUCT RULE)

The product rule is discussed in Section 2. 5 of Volume I and is used in Section 4. 3 of Volume II. A discussion of this rule is given in the following paragraphs.

A series system is a series of single elements in which failure of any one element will result in failure of the total system. Thus, symbolically, if S_i denotes success of the i^{th} subsystem, and S denotes success of the overall system, then,

$$S = S_i \cap S_2 \cap S_3 \cap \ldots \cap S_k$$

which states that the event S occurs when and only when every S_i occurs. The symbol "$\cap$" denotes event intersection or logical product, or simply "and." Hence,

$$P(S) = P(S_1 \cap S_2 \cap \ldots \cap S_k)$$

where P(S) is the probability of success, or reliability of the overall system. The above equation states that the reliability of the system is the probability that all of the subsystems are successful. Now, if it is assumed that failure in any of the subsystems occurs independently of failure in any of the remaining subsystems or equivalently that success in any of the subsystems is independent of success in any of the remaining subsystems, then the probability of the logical product of events on the right-hand side of the equation is equal to the product of the individual probabilities of the events. Hence,

$$P(S) = P(S_1)P(S_2) \cdots P(S_k)$$

or denoting the reliabilities of the subsystems and system by R_1, R_2, ..., R_k and R, respectively, we have the "product rule"

$$R = R_1 \cdot R_2 \cdots R_k$$

B.2 THE BINOMIAL DISTRIBUTION

The binomial distribution is discussed in Section 2. 5 of Volume I and is applied in Section 4. 3 of Volume II. A derivation for this distribution is presented in the following paragraphs.

Let p be the probability that an event will occur at a single trial, and let $q = 1 - p$ denote the probability that it will fail to occur. If the event occurs at a given trial, it is a success. If the event fails to occur at a given trial, it obviously is a failure. Let n independent trials be made, and denote by x the number of successes observed in n trials. Then consider the problem of determining the probability of obtaining precisely x successes in n trials.

First, determine the probability of obtaining x consecutive successes, followed by n - x consecutive failures. These n events are independent; therefore this probability is

$$\overbrace{p \cdot p \cdots p}^{x} \cdot \overbrace{q \cdot q \cdots q}^{n-x} = p^x q^{n-x}$$

The probability of obtaining precisely x successes and n - x failures in some other order of occurrence is the same as for this particular order because the p's and q's are merely rearranged to correspond to the other order. To solve the problem, it is therefore necessary to count the number of such orders.

The number of orders is the number of permutations possible with n letters of which x are alike (p's) and the remaining n - x are alike (q's). The number of permutations of n things of which n_1 are alike, n_2 are alike, $\cdots$, and n_k are alike is given by

$$\frac{n!}{n_1!\, n_2! \cdots n_k!}$$

A direct application of this formula shows that the number of permutations of the p's and q's is equal to

$$\frac{n!}{x!\,(n-x)!}$$

The probability that one or the other of the set of mutually exclusive events will occur is the sum of their separate probabilities; consequently it is necessary to add $p^x q^{n-x}$ as many times as there are different orders in which the desired result can occur. Therefore, the probability of obtaining x successes in n independent trials of an event, for which p is the probability of success in a single trial, is given by

$$P(x) = \frac{n!}{x!(n-x)!} p^x q^{n-x}$$

This function is called the binomial or Bernoulli distribution function. The name binomial comes from the relationship of $P(x)$ to the binomial expansion:

$$(q+p)^n = q^n + nq^{n-1} p + \frac{n(n-1)}{2!} q^{n-2}p^2 + \cdots + p^n = \sum_{x=0}^{n} P(x)$$

In the application required for the present report the concern is the probability of n successes in n independent trials. For this case

$$P(n) = \frac{n!}{n!0!} p^n q^0$$

$$= p^n$$

$$= R(n), \text{ or reliability}$$

Thus, the reliability of a particular component (whose probability distribution is binomial) is the n^{th} power of the probability of success of a single trial, where n specifies the number of cycles the component is required to operate in performance of its function.

B.3 THE EXPONENTIAL DISTRIBUTION

The exponential distribution is discussed in Section 2. 5 Volume I and is applied in Section 4. 3 of Volume II. A derivation for this distribution is given in the following paragraphs.

Basically the exponential distribution is an example of the Poisson distribution, although as mentioned in Volume I it also occurs as a special case of both the Gamma and the Weibull distributions. The following material presents a background for the exponential distribution by discussing the more general Poisson distribution.

The function which gives the probability of occurrence of exactly x events in a time interval to where individual events occur independently and at random with a rate λ is called the Poisson distribution. If P(x) is used as a symbol for this probability, then

$$P(x) = \frac{(\lambda t)^x e^{-\lambda t}}{x!}$$

This relation can be derived by accepting a more precise definition of the random rate of occurrence of a single event.

a) The probability that a single event occurs in any interval Δt is $\lambda \Delta t + o(\Delta t)$, where $o(\Delta t)$ means a term such that

$$\lim_{\Delta t \to 0} \frac{o(\Delta t)}{\Delta t} = 0$$

and is read "a term of higher order than Δt."

b) The probability that two or more events occur in any interval Δt is $o(\Delta t)$.

Therefore, if the interval t is divided into m subintervals Δt, the use of the binomial distribution shows that

$$P(x) = \lim_{\Delta t \to 0} \frac{m!}{x!(m-x)!} \left[\lambda \Delta t + o(\Delta t)\right]^x \left[1 - \lambda \Delta t + o(\Delta t)\right]^{m-x}$$

$$= \lim_{\Delta m \to \infty} \frac{m!}{x!(m-x)!} \left(\frac{\lambda t}{m}\right)^x \left(1 - \frac{\lambda t}{m}\right)^{m-x}$$

since

$$\Delta t = \frac{t}{m}$$

or

$$P(x) = \frac{(\lambda t)^x}{x} \lim_{m \to \infty} \frac{m!}{m^x (m-x)!} \lim_{m \to \infty} \left(1 - \frac{\lambda t}{m}\right)^{m-x}$$

$$P(x) = \frac{(\lambda t)^x e^{-\lambda t}}{x!}$$

since

$$\lim_{m \to \infty} \frac{m!}{m^x (m-x)!} = \lim_{m \to \infty} \left(1 - \frac{1}{m}\right) \cdots \left(1 - \frac{x-1}{m}\right) = 1$$

and

$$\lim_{m \to \infty} \left(1 - \frac{\lambda t}{m}\right)^{m-x} = e^{-\lambda t}$$

The exponential distribution arises from the Poisson distribution when $x = 0$:

$$P(0) = e^{-\lambda t}$$

which is the probability of no events (e.g., failures) occurring in the interval 0 to t. The exponential distribution applies to devices which operate continuously and which can fail at any time with a constant failure rate.

B.4 MAXIMUM LIKELIHOOD ESTIMATES OF p AND λ

Estimates of the parameter p in the binomial distribution and of λ in the exponential distribution can be obtained from statistical test data. Particular expressions for estimates of p and λ in terms of directly measureable quantities (as given in Section 2.5 of Volume I) can be derived through the concept of the likelihood function. If an event occurs at time t_i and if the probability of this event occurring at t_i has (or is assumed to have) a functional dependence on t_i represented by $P(t_i;h)$ where h is a a parameter of the distribution (such as p or λ); then a likelihood function can be defined as

$$L(h) = \prod_i P(t_i;h)$$

Then the maximum likelihood estimate of h is that value which maximizes L(h), i.e., solving

$$\frac{dL(h)}{dh} = 0 \qquad\qquad \frac{d^2L(h)}{dh^2} < 0$$

gives the value of $\hat{h}$, the maximum likelihood estimator of h, in terms of the values of the t_i.

Consider the case of a group of N devices, which are assumed to follow the exponential failure distribution and are placed on test. Suppose that F failures occur at time t_1 to t_F. The probability that a failure will occur in a small time interval Δt at t_i is $-\left(de^{-\lambda t_i}/dt\right)\Delta t$. Let the test be terminated at time t_{F+1} when N - F units are still unfailed. The probability of this occurrence is $e^{-\lambda(N-F)t_{F+1}}$. Then a likelihood function can be formed:

$$L(\lambda) = \lambda^F \left[e^{-\lambda \sum_{i=1}^{F} t_i}\right] (\Delta t)^F \; e^{-\lambda(N-F)t_{F+1}}$$

and

$$\frac{dL}{d\lambda} = (F\lambda^{F-1} e^{-\lambda T} - T\lambda^F e^{-\lambda T})(\Delta t)^F$$

where

$$T = \sum_{i=1}^{F} t_i + (N-F)t_{F+1}$$

$$= \text{total device operating time}$$

Setting $\frac{dL}{d\lambda} = 0$:

$$F = T\hat{\lambda}$$

$$\hat{\lambda} = \frac{F}{T}$$

Since $L(0) = L(\infty) = 0$ and $L(\lambda) \geq 0$ for $\lambda \geq 0$, the value $\hat{\lambda}$ must maximize $L(\lambda)$.

In the binomial distribution a maximum likelihood estimator for p when S successes occur in N trials can be found by solving:

$$\frac{d}{dp} L(p) = \frac{d}{dp}\left[p^S (1 - p)^{N-S}\right] = 0$$

$$S\hat{p}^{S-1}(1 - \hat{p})^{N-S} - (N - S)(1 - \hat{p})^{N-S-1}\hat{p}^S = 0$$